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Cuadernos de Geomática

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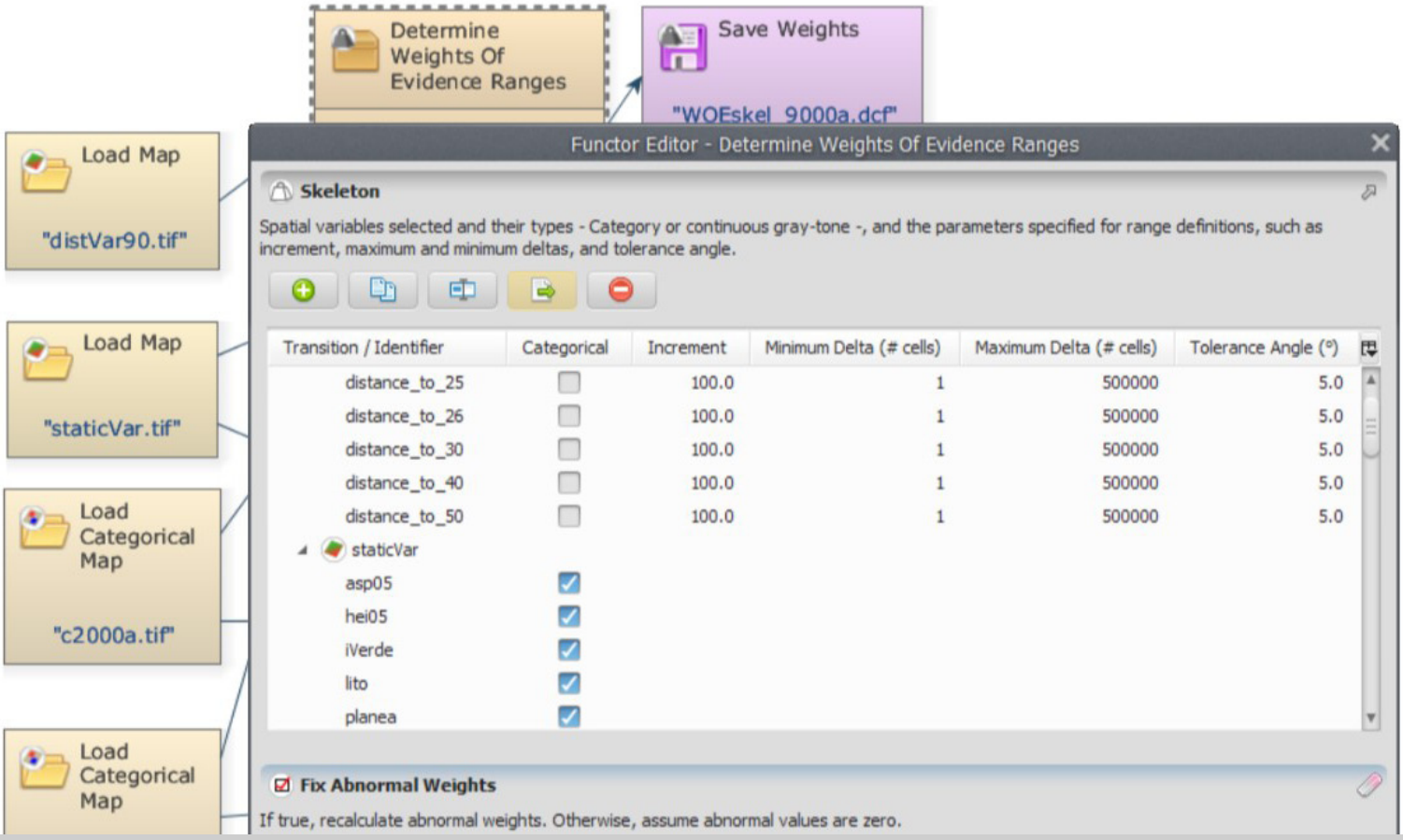

La Geomática y sus herramientas para el análisis de los recursos hídricos en 2023

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Notes on Geomatics. 9

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PREFACIO

El nuevo número de Cuadernos de Geomática, La Geomática y sus herramientas para el análisis de los recursos hídricos en 2023, es, en realidad, una actualización de una publicación anterior: La Geomática en el análisis de los recursos hídricos (2018). La fecha que aparece en el título es ya indicativa de la necesidad de poner al día la edición anterior cinco años después y, también, de revisar las áreas de trabajo y las aplicaciones que en ellas se dan.

En este nuevo número se ha mantenido la estructura general y la organización por capítulos que tenía la versión anterior. Sin embargo, se ha realizado una exhaustiva revisión de todos los contenidos de manera que estos quedaran actualizados adecuadamente en cuanto a las publicaciones y líneas de investigación y la vigencia e interés de los programas que se presentan. Asimismo, todos los trabajos que se utilizan como ejemplo están de libre acceso en ITERNET.

El contenido del nuevo número hereda la división temática de la publicación de 2018. Aunque se ha mantenido en la medida de los posible la agrupación especializada de las aplicaciones, algunas han sido modificadas por coherencia temática y, también se ha incorporado alguna nueva, fruto de la evolución lógica de las estructuras digitales, como es el caso de la accesibilidad a datos y repositorios de información.

Tras la introducción sobre la Geomática y los programas de libre acceso aplicados en hidrología, el libro se ha dividido en las siguientes secciones temáticas:

A. Sistemas de Información Geográfica y Teledetección
B. Modelos hidrológicos, hidráulicos e hidrogeomorfológicos (erosión)
C. Análisis de imágenes
D. Estadística y Geoestadística
E. Calidad Cartográfica
F. Programas de Apoyo
G. Sistemas de Datos

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¿QUÉ ES LA GEOMÁTICA?

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Es común que los términos Geomática y Sistemas de Información Geográfica (SIG) se utilicen como sinónimos, aunque de manera equivocada, pues en realidad no significan lo mismo (Bédard, 2007). Entre ellos existen diferencias sustanciales, considerándose hoy en día los SIG como una disciplina integrante de la Geomática.

Esta simplificación se debe a que normalmente, se utiliza la acepción SIG para referirse de manera genérica a los programas que trabajan con información espacial. El primero que acuñó el término de SIG fue Robert Tomlinson a mediados del siglo XX, en el proceso de creación de una herramienta para el programa de desarrollo rural de Canadá basada en el uso de computadoras para el almacenamiento, clasificación y manipulación de datos terrestres con mapas (Tomlinson, 1968). Son precisamente estas últimas atribuciones, entre otras, las que marcan las diferencias entre lo que se entiende por SIG y lo que se entiende por Geomática (Maguire, 2010).

Por otro lado, la definición de Geomática la realizó Michel Paradis en los años ochenta, en la Universidad de Laval (Canadá), al entender que el creciente potencial de la informática iba a revolucionar la manera de representar el territorio y los objetos geográficos (Gomarasca, 2009). Esta "nueva" ciencia consistía en la integración de las disciplinas tradicionales de medición espacial con los métodos modernos de captación, tratamiento, almacenamiento y difusión de los datos geográficos (Paradis, 1981). Cabe destacar que el término Geomática apareció por primera vez en Francia a principios de 1970, aunque en su definición sólo se mencionaban las actividades de mapeo asistido por ordenador (Bédard, 2007), sin tener en consideración los demás aspectos que sí tuvo en cuenta Paradis años después. A partir de ese momento comenzó a incluirse en el ámbito universitario, siendo en la Universidad de Laval dónde en 1986 se ofertó el primer programa académico de Geomática del mundo, la licenciatura en Ciencias Geomáticas (Bédard y Gagnon, 1987). Posteriormente también cambiaron el nombre del Departamento y crearon el Centro de Geomática a la vez que aunaron las actividades de investigación de seis laboratorios independientes (metrología, fotogrametría, cartografía, topografía, teledetección y Sistemas de Información Geográfica) bajo uno sólo, "Laboratorio de Geomática". Esta restructuración de la universidad canadiense creó un impulso que se extendió a otras partes: empresas privadas, administraciones, asociaciones y otras universidades crearon divisiones y departamentos Geomáticos o se identificaban como organizaciones de Geomática (Bédard, 2007).

La evolución de las técnicas cartográficas y topográficas se ha caracterizado por una relativa lentitud hasta la segunda mitad del siglo XX, cuando se introdujo el ordenador (Ajvazi et al., 2016). Los acelerados avances que experimentan la electrónica y la informática, ciencias a las cuales la Geomática está indisolublemente ligada, y las tendencias mostradas, durante algo más de dos décadas, permiten estimar que, en el corto, mediano y largo plazo, se acrecentará la importancia de esta disciplina en la investigación geográfica (Flores, 1998). De esta manera, la informática empezó a formar parte del trabajo de topógrafos y cartógrafos cambiando de forma radical el modo de adquisición, procesamiento, análisis y representación cartográfica. En la actualidad, la amplia disponibilidad y el uso de tecnologías sofisticadas, como los sistemas mundiales de navegación por satélite (GNSS), la teledetección y los Sistemas de Información Geográfica aumentan la precisión y la productividad siendo parte esenciales de la Geomática.

Por lo tanto, la tecnología geomática, incluyendo los Sistemas de Información Geográfica y la Teledetección, es la técnica geoespacial para recopilar, gestionar, analizar y difundir información referenciada espacialmente (Yang, 2017). Del mismo modo, Konecny afirma que la Geomática está compuesta por las disciplinas de geoposicionamiento, mapeo y gestión de datos espaciales por medio de ordenadores, emergiendo recientemente como una nueva disciplina por medio de la integración de los levantamientos topográficos y cartográficos fusionados con la teledetección y los SIG. Además, la Geomática se ha abierto a aplicaciones de valor añadido de muchas otras disciplinas empleando datos espacialmente referenciados (Konecny, 2002). Otra de las definiciones más recientes de Geomática la reconoce como las matemáticas de la Tierra; siendo considerada la ciencia de la recopilación, análisis e interpretación de datos,

especialmente datos instrumentales, relacionados con la superficie de la Tierra (Deshogues y Gilliéron, 2009).

Retomando el binomio SIG-Geomática, debería distinguirse en que un Sistema de Información Geográfica es una subdisciplina de la Geomática, como también lo son la Teledetección y los sistemas automáticos de recogida de datos espaciales, mientras que la Geomática es el marco amplio, científico-técnico en el que se insertan las anteriores técnicas. En palabras de Maguire (2010): la Geomática o Ciencia de la información espacial, "permite considerar los contextos filosóficos, epistemológicos y ontológicos y los Sistemas de Información Geográfica proveen la infraestructura, herramientas y métodos para abordar los problemas del mundo real dentro de un marco temporal aceptable".

Contexto científico-técnico de la Geomática

En la Figura 1 se observa la variedad de ciencias y disciplinas que se integran en el amplio paraguas de la Geomática. Ésta, como ciencia central, está compuesta por un grupo principal de disciplinas que le dan identidad propia como los sistemas de referencia geodésica, la teledetección, los sistemas de posicionamiento global y los SIG. Sin embargo, además de su propio cuerpo de conocimiento necesita recurrir a un conjunto de ciencias auxiliares que le facilitan su construcción epistemológica (las matemáticas, las tecnologías de satélite, la física, etc.). Sin embargo, la Geomática es también una disciplina de apoyo cuyos resultados y productos pueden ser utilizados para cubrir una amplia y diversa demanda cuya característica común es el análisis y representación de fenómenos espaciales (cartografía, inventarios catastrales, gestión territorial, aplicaciones de la teledetección), entre los que también se incluyen la hidrología.

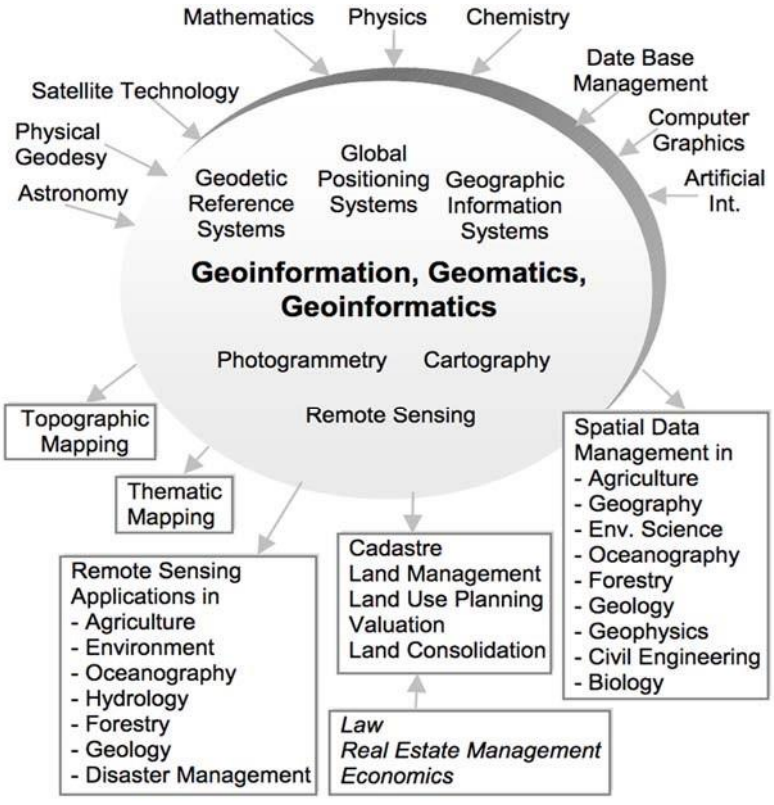

Figura 1. Ciencias y disciplinas que apoyan e inciden en la Geomática (Konecny, 2002).

Dicho de otra manera, la Geomática, como área de conocimiento, descansa en una serie de disciplinas cuyas características y funcionalidades son las siguientes (Gomarasa, 2009):

- Informática: para representar y procesar información aplicable a través del desarrollo de instrumentos tecnológicos (hardware) y de métodos, modelos y sistemas (software).
- Geodesia: para determinar la forma y el tamaño de la Tierra; define, por un lado, la superficie de referencia en su forma completa, el geoide, así como en su forma simplificada, el elipsoide y, por otro lado, el campo gravitacional externo en función del tiempo.
- Topografía: una combinación de métodos e instrumentos para medir y representar detalladamente la superficie de la Tierra, como la planimetría, la altimetría y el reconocimiento topográfico.
- Cartografía: para proporcionar una posible descripción de la forma y dimensión de la Tierra y sus detalles naturales y artificiales, mediante representación gráfica o numérica de áreas más o menos amplias, siguiendo reglas fijas.
- Fotogrametría: para determinar la posición y las formas de los objetos midiéndolos en imágenes fotográficas.
- Teledetección: para adquirir de forma remota datos territoriales y ambientales, y para combinar métodos y técnicas para su posterior procesamiento e interpretación (esta definición también se ajusta a la fotogrametría digital).
- Sistemas de posicionamiento global (GPS): para proporcionar la posición tridimensional (3D) de objetos fijos o en movimiento, en el espacio y el tiempo, en toda la superficie de la Tierra, bajo cualquier condición meteorológica y en tiempo real.
- Sistema de escaneo láser: para localizar objetos y medir su distancia por medio de la radiación incidente en las frecuencias ópticas (0.3-15 μm) del espectro electromagnético.
- Sistema de información geográfica (SIG): para hacer uso de una poderosa combinación de instrumentos capaces de recibir, registrar, almacenar, transformar, representar y procesar datos espaciales georreferenciados.
- Sistemas de apoyo a la toma de decisiones (SATD): para implementar Sistemas de Información Geográfica complejos, destinados a crear posibles escenarios modelando la verdad del terreno y ofreciendo un conjunto de soluciones al que toma las decisiones.
- Sistemas expertos (SE): instrumentos capaces de imitar los procesos cognitivos de los expertos y su capacidad para gestionar la complejidad de la realidad mediante procesos interdependientes de abstracción, generalización y aproximación.
- SIG en la Web: para distribuir datos geográficos almacenados de forma remota en máquinas dedicadas para bases de datos, de acuerdo con arquitecturas de red complejas.
- Ontología: para especificar una conceptualización, es decir, la descripción de conceptos y relaciones existentes en un elemento o entre varios elementos de un grupo, entidad o clase; es una visión abstracta simplificada del mundo que se representará para una aplicación determinada.

La Geomática aplicada al estudio del agua

De manera genérica, la Geomática proporciona los instrumentos para respaldar cualquier estudio con componente espacial, incluidos, lógicamente, los dedicados a la evaluación, protección y gestión de los recursos naturales (Papatheodorou et al., 2017). En pocos decenios se ha convertido en una herramienta poderosa para el manejo de datos espaciales y también para la toma de decisiones en varias áreas, incluyendo ámbitos ingenieriles y/o medioambientales (Goodchild et al., 1993; Stafford, 1991).

Sin embargo, dentro de ese amplio espectro de aplicaciones y utilidades que tiene, la Geomática se posiciona como un elemento fundamental dentro de los estudios relacionados con la hidrología y los recursos hídricos, pues en ellos la adquisición, gestión y/o uso de información espacial son cruciales. Estos trabajos comprenden enfoques multidisciplinares debido a su amplia gama de aplicaciones en las que deben incluirse conocimientos expertos de distintas ramas: análisis de inundaciones, erosión, hidráulica, modelos numéricos, hidroeconomía, suministro de agua, calidad del agua y contaminación, etc. Muchos de estos estudios requieren medidas de campo precisas y confiables para el análisis posterior (Molina et al., 2014), pues la efectividad de las acciones para una gestión y protección sostenible de los recursos hídricos se basa en la adquisición, disponibilidad, fiabilidad y precisión de la información espacial (Molina et al., 2014).

En consecuencia, el número y variedad de programas que van a formar parte de un estudio de recursos hídricos con dimensión espacial puede ser, en función de la naturaleza del mismo, muy amplio. Por ejemplo, en el análisis sobre política del agua se incluyen procesos físicos, biológicos, económicos, sociales y políticos complejos que se manifiestan a distintas escalas espaciales (nivel de cuenca y subcuencas hidrográficas ya sea de manera regional, nacional o internacional). La política del agua tiene una dimensión inherentemente espacial que necesita del apoyo de las técnicas geomáticas.

Desde el punto de vista práctico, las aplicaciones de la Geomática se pueden sintetizar con tres grandes premisas:

1. La Geomática permite la adquisición, almacenamiento, gestión, visualización y distribución del agua y sus datos asociados;
2. los análisis espaciales de los recursos hídricos realizados con SIG y modelos hidráulicos forman parte de la Geomática;
3. la Geomática es esencial en el desarrollo de sistemas de apoyo a las decisiones relacionados con los recursos hídricos (Yang, 2017).

Geomática: un mundo de programas, incluidos los de libre acceso

Por otra parte, la utilización de la Geomática, sobre todo gracias al progreso de las tres últimas décadas, brinda a la comunidad científica un conjunto de técnicas y metodologías de trabajo cuyo coste no tiene porque ser excesivamente alto cuando se trata de adquirir programas, incluso sin coste en algunos casos, si se recurre a las opciones de licencias libres. Esto tiene un impacto directo en el uso más eficiente de los recursos económicos que afectan a administraciones públicas y empresas privadas (Zazo et al., 2015).

Sin embargo, elegir el “método geomático” correcto para una acción determinada sigue siendo un desafío en este campo. La razón principal es la complejidad de las diferentes aplicaciones y variables involucradas en la gestión de los recursos hídricos (Molina et al., 2014). Si se excluye el tipo

de maquinaria que se necesita, tan sólo la elección de los programas que pueden acometer las tareas requeridas puede convertirse en algo tedioso y confuso. En la actualidad, la combinación de programas de distinta naturaleza (y no únicamente de análisis geográfico) para el análisis de los recursos hídricos es ya algo común. Un ejemplo de ello es la caracterización espacial de los contaminantes de origen agrícola realizada en el río Júcar (Pascual Aguilar et al., 2017) en el que se combinan el diseño de muestreo y geolocalización de los puntos de toma de agua con Orux maps, técnicas de extracción de información espacial con ARCGIS, elaboración de resúmenes tabulados y obtención de inferencias estadísticas sencillas con Microsoft Office y el análisis de componentes principales multivariante con SPSS, todos ellos, a excepción de Orux maps, bajo licencia comercial.

Sin embargo, un diseño analítico similar al propuesto en el ejemplo anterior también es posible utilizando programas de acceso libre. Precisamente, el manual para evaluar el papel que juegan los ecosistemas costeros y marinos en mitigar la erosión de las playas (Chatenoux, et al., 2012), elaborado en el marco del Risk and Vulnerability Assessment Methodology Development Project (RIVAMP), plantea una sistemática de uso de programas libres combinando QGIS, SIG equivalente a ARCGIS; la suite ofimática LibreOffice, similar a Microsoft Office y Tanagra un programa de análisis estadístico parecido a SPSS, aunque algo menos sofisticado.

En consecuencia, junto al mundo de los programas con licencias comerciales se ha ido desarrollando también un conjunto de iniciativas que han apostado por la creación de aplicaciones libres, con las que se evitan los continuos mantenimientos de licencias, la supeditación a las leyes de mercado y se gana el acceso directo al código fuente de los programas.

Por consiguiente, si se atiende a las necesidades que cualquier estudio de análisis espacial exige, señaladas en la figura 1, se observa que no se trata tan sólo de incorporar en la estructura geomática que se diseñe sólo programas de análisis específicos de la disciplina. Debe también pensarse en un conjunto de recursos que trasciende las necesidades específicas de una disciplina concreta como, en el caso que nos concierne, los recursos hídricos. Junto a estos programas como los SIGs, la Geoestadística, la Cartografía y la Teledetección, hay que pensar en otros que facilitan la recogida de información geo-referenciada en campo y la calidad de la geolocalización de los datos y mapas existentes; o de la utilización de aplicaciones estadísticas genéricas e, incluso, el uso de programas de ofimática.

Son sobre todo los SIGs los que mayor desarrollo han tenido como software libre. Existen varias alternativas a los softwares comerciales con unas capacidades y características muy similares a éstos (Khan, 2017). Algunos SIG de código abierto poseen unas funcionalidades muy apropiadas para la realización de estudios espaciales como son QGIS, gvSIG, GRASS o ILWIS, entre otros (Maurya et al., 2015).

Un rápido recorrido por trabajos publicados utilizando programas de libre acceso nos muestra la diversidad que existe. Son, por tanto, cada vez más numerosos los trabajos, de muy diversa naturaleza, sobre los recursos hídricos que emplean técnicas geomáticas en alguna de sus fases de investigación.

Hay investigaciones sobre aspectos relacionados con la efectividad de las diferentes modalidades de programación de riego en cultivos

de trigo y caña de azúcar teniendo en cuenta variables ambientales y climáticas empleando sensores remotos y tecnologías SIG (Singh et al., 2011). Otro trabajo que ha empleado la Teledetección y los SIG, usando además únicamente software libre, es el relacionado con la protección y gestión del agua subterránea de una zona de Grecia (Papatheodorou et al., 2017). Concluyen que estas disciplinas ayudan a definir zonas de recarga para la protección del agua subterránea y los usos de la tierra, incluidas las prácticas agrícolas y los tipos de cultivo.

Por otra parte, se pueden destacar también los trabajos relacionados con la gestión de sistemas económicos y medioambientales de cuencas hidrográficas empleando un sistema de soporte a la decisión el programa AQUATOOL, (Pedro-Monzonís et al., 2016) o aquellos que evalúan los riesgos relacionados con el cambio climático asociado a cuencas hidrográficas (Momblanch et al., 2015).

Otro tipo de programas que se emplean de manera muy común en los estudios relacionados con los recursos hídricos son los programas de análisis estadístico como, por ejemplo, R y PSPP. El primero es un recurso muy utilizado en el ámbito académico y en la investigación, pudiéndose destacar algunos trabajos relacionados con modelos hidrológicos y evapotranspiración de agua en procesos agrícolas (Coron et al., 2017; Turner y Galelli, 2016). El segundo se ha empleado en investigaciones relacionadas con la modelización hidráulica o los tratamientos de aguas residuales (Juntawang et al., 2017; Lotz et al., 2017).

Son, sin embargo, los SIG los que tienen atribuida la componente espacial por antonomasia, permitiendo una amplia y variada gama de análisis. Dentro del mundo de las aplicaciones de código libre, son QGIS, gvSIG, ILWIS y GRASS los que mayor ascendente tienen entre los usuarios. QGIS por su parte ha sido empleado, por ejemplo, en la creación de un sistema de modelización hidrológica cuya capacidad ha sido demostrada en una cuenca hidrográfica de 430 km^2 en Pennsylvania, Estados Unidos (Bhatt et al., 2014). gvSIG ha sido usado en estudios sobre contaminación del agua en el acuífero no confinado de Montes Torozos, en España, en el que el punto de partido fue la identificación del origen de los contaminantes y el transporte de los mismos (Martínez-Alegría et al., 2014). También hay trabajos realizados con ILWIS, un ejemplo es el análisis sobre la gestión del recurso hídrico en la evaluación de la vulnerabilidad a riesgos hidrometeorológicos (Godfrey et al., 2015). Ejemplo del uso de GRASS es la aplicación para análisis y modelización del flujo de agua subterránea planteada por Carrera-Hernández y Gaskin (2006).

La variedad de software de modelización hidrológica es muy amplia. La inquietud por construir programas cada vez más sofisticados que incorporen la mayor y mejor representatividad de los procesos ha sido una constante de la hidrología. A ello se le une la necesidad de poder caracterizar de manera fiable la hidrología de sistemas para su correcta gestión. El resultado final es una altísima variedad de modelos hidrológicos tanto comerciales como de libre de acceso. De entre estos últimos destacan un buen número que han conseguido consolidarse y tener una comunidad de usuarios amplia y variada como, por ejemplo, HEC-HMS, HEC-RAS, Iber, Modflow, SWMM, Tetis y WEPP. HEC-

HMS y HEC-RAS son programas desarrollados por el Centro de Ingeniería Hidrológica (HEC) del Cuerpo de Ingenieros del Ejército de los EEUU. HEC-HMS ha sido empleado, por ejemplo, en simulaciones de escorrentía en una cuenca hidrográfica de Malasia

(Kwin et al., 2016) o en la previsión de las inundaciones en la cuenca del río San Antonio en Texas en colaboración con software SIG (Knebl et al., 2005). Por su parte, HEC-RAS se ha usado para evaluar la relación entre el flujo de agua superficial y subterránea en un arroyo en Ontario, Canadá (Drake et al., 2010) o en estudios de inundaciones históricos o paleohidrología en una zona de Utah, Estados Unidos (Carson, 2006). Iber es un programa que se ha empleado, entre otros, en el estudio del comportamiento hidráulico de canales artificiales (Corestein et al., 2014). Modflow es uno de los programas más utilizados en modelización hidrológica a nivel mundial, destacando sus aplicaciones en la estimación de parámetros hidráulicos para la evaluación del agua subterránea (Assari y Mohammadi, 2017) o los estudios de recarga de acuíferos para la gestión adecuada de los recursos hídricos (Jones et al., 2015). SWMM se ha usado en trabajos sobre urbanismo medioambiental ligado a la modelización del agua de lluvia (Cipolla et al., 2016), mientras que Tetis ha destacado en estudios de inundaciones, como el establecimiento de periodos de retorno de inundaciones en la cuenca hidrográfica del Júcar (Botero y Francés, 2010).

Algunos modelos no son específicamente hidrológicos, pero pueden servir para abundar en el conocimiento de fenómenos relacionados con la hidrología. Uno de ellos, basado en el análisis de tendencias de futuro aplicando cadena de Markov y autómatas celulares, denominado Dinamica EGO, ha sido empleado en estudios sobre gestión de recursos hídricos como la modificación del balance hídrico regional en una zona deforestada con del Amazonas (Lima et al., 2014). Otro ejemplo son los modelos de erosión hídrica, como el programa WEPP, que se ha utilizado en estudios para la estimación de la capacidad de transporte de sedimentos de ríos y arroyos (Mahmoodabadi et al., 2014) y en trabajos sobre gestión de cuencas hidrográficas, como el realizado en la cuenca del lago Tahoe de Estados Unidos (Brooks et al., 2016).

Estamos en una época en la que las tecnologías espaciales, bajo el nombre de Geomática, han avanzado sustancialmente. En paralelo, los programas de libre acceso han ido progresando hasta el punto de convertirse en una alternativa a los de acceso bajo licencia. Sin embargo, la elección de este tipo de aplicaciones no sólo está relacionada con su precio, sino que también deben tenerse en cuenta otros factores como la posibilidad de acceder libremente al uso de los programas y su código fuente (Moreno-Sanchez, 2012).

Sin embargo, los recursos de las nuevas tecnologías de la información espacial, no solamente se limitan a los programas de libre acceso. No hay que perder de vista la evolución ocurrida también en los consorcios y redes sobre técnicas geomáticas, grupos de usuarios sobre programas concretos, y la disponibilidad, también de libre acceso, de grandes volúmenes de datos que pueden ser usados en análisis espaciales.

El acceso libre a la información (datos abiertos) cobra especial valor en la optimización de recursos en los proyectos que se apoyan en la Geomática, pues permiten a cualquier persona su uso, distribución y reutilización, incluso con fines comerciales, sin necesidad de pedir explícitamente permiso al propietario de los datos (Baltussen et al., 2013). Muchas organizaciones gubernamentales y no gubernamentales ya publican abiertamente partes de sus datos para que cualquier ciudadano pueda consultarlos y trabajar con ellos (Brodeur et al., 2000), dándole una nueva dimensión al

concepto de libre acceso de las tecnologías geomáticas.

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A. SISTEMAS DE INFORMACIÓN GEOGRÁFICA Y TELEDECCIÓN

A1. QGIS

CG9. A1

1. Descripción

QGIS es un Sistema de Información Geográfica de código libre para las principales plataformas de sistemas operativos que existen. Permite manejar formatos raster y vectoriales y bases de datos. QGIS está desarrollado en C++ y permite la integración de plugins desarrollados tanto en C++ como Python.

QGIS al igual que otros SIG permite la visualización, administración, edición y análisis de datos, así como la composición de mapas. Este programa posee una interfaz de usuario sencilla e intuitiva, además de una fácil visualización de numerosos formatos raster y vectoriales (incluyendo bases de datos PostGIS). Este programa incluye una potente funcionalidad de análisis ya que se integra con GRASS GIS permitiendo crear, editar y exportar datos espaciales. De manera más específica posee complementos de modelado hidrológico, álgebra de mapas, análisis de terreno, análisis de redes, etc.

QGIS era conocido en un principio como Quantum GIS, siendo uno de los primeros ocho proyectos de la Fundación OSGeo, siendo su lanzamiento inicial en 2002. Al ser un software libre y de código abierto, el programa puede ser modificado libremente de tal manera que pueda realizar diferentes y más especializadas funcionalidades.

Las principales investigaciones en las que se ha usado QGIS recientemente son Congelo, 2021; Jakimow et al., 2023; Khan et al., 2023; Kpiebaya et al., 2022; Lee et al., 2022; Muhammad et al.,2023 y Reynés et al., 2023.

2. Características técnicas

Programa	QGIS desktop		
Versión	3.28.7 LTR	Año	2023
Tipología	Sistemas de Información Geográfica, Teledetección		
Capacidades del programa	QGIS es un Sistema de Información Geográfica de código abierto que funciona con las mayorías de las plataformas operativas. QGIS permite visualizar datos vectoriales y raster en diferentes formatos y proyecciones. También puede componer mapas y explorar datos espaciales, además de crear, editar, gestionar y exportar estos datos. QGIS permite analizar los datos por medio de análisis espaciales tales como análisis de vectores, muestras o geoprocesamiento. Por último, entre otras muchas funcionalidades, QGIS se puede usar como cliente WMS, WMTS, WCs o WFS y WFS-T, y como servidor para la publicación de mapas en internet. Complementos del núcleo: Georeferencer GDAL (agregar información de proyección a rásteres usando GDAL) Herramientas GPS (cargar e importar datos GPS) GRASS (integrar SIG GRASS) Complementos externos de Python		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (64 bits)		
	macOS X (64 bits) High Sierra (10.13) o posterior		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	Open Source Geospatial Foundation (OSGeo)		
Web	https://qgis.org		

3. Ejemplos de trabajos científicos

The Journal of Open Source Software

Semi-Automatic Classification Plugin: A Python tool for the download and processing of remote sensing images in QGIS

Luca Congedo[1]

1 Independent Researcher

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Software

- Review
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- Archive

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Summary

The `Semi-Automatic Classification Plugin` is a Python plugin for the software QGIS (QGIS Development Team, 2021) developed with the overall objective to facilitate land cover monitoring by people whose main field is not strictly remote sensing, but that could benefit from remote sensing analysis. The `Semi-Automatic Classification Plugin` provides a set of intertwined tools and a user interface for easing and automating the phases of land cover classification, from the download of remote sensing images, to the preprocessing (i.e. tools for preparing the data to the analysis or other calculations), the processing (i.e. tools for performing the classification of land cover or perform analysis), and postprocessing (i.e. tools for assessing the classification accuracy, refining the classification, or integrating additional data). The processing of remote sensing data can be computationally intensive, therefore most of the developed tools use Python multiprocessing to exploit the system CPU and RAM by splitting the work among multiple subprocesses. The aim of this paper is to describe the main characteristics of the `Semi-Automatic Classification Plugin` for the land cover classification of remote sensing images.

Statement of need

Remote sensing is the measurement, by a sensor installed on board of airplanes or satellites, of the energy that is emanated from the Earth's surface (Richards & Jia, 2006). Remote sensing images are spatial data and require the use of a Geographic Information System (GIS) for visualization and processing. The free availability of satellite data (such as Landsat (United States Geological Survey, 2019), and Sentinel-2 (European Space Agency, 2018)) extended the use of remote sensing in various fields such as urban planning, agriculture, environmental monitoring, etc. (Nink et al., 2019; Pesaresi et al., 2016; Rogan & Chen, 2004; Weiss et al., 2020). Land cover is defined as the material at the Earth's surface, such as soil, vegetation, water, asphalt, etc. (Fisher & Unwin, 2005). A supervised classification (also known as semi-automatic classification) is an image processing technique that aims at classifying land cover by training an algorithm with samples of material spectral signatures.

The development of open source GIS and processing software can foster environmental monitoring, which can be performed with no cost for software and remote sensing images considering the free data availability. QGIS is an open source GIS software which provides several tools for data visualization and analysis; it is mainly written in C++ code, but it also allows to extend the functions thereof through API and plugins written in Python (QGIS Development Team, 2021). QGIS has a large repository of plugins that improve data analysis and also provide access to several image processing tools included in other open source programs such

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Original software publication

EnMAP-Box: Imaging spectroscopy in QGIS

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ABSTRACT

Satellite missions like EnMAP and PRISMA generate raster images that describe the Earth's environment with hyperspectral resolution. Such imaging spectroscopy data is of high value for applications in, e.g., geological, vegetation, or hydrological research. Due to its high dimensionality, analyzing imaging spectroscopy data is still challenging and often requires the use of proprietary software. The motivation for the EnMAP-Box is to close this gap and to foster the use of imaging spectroscopy data with state-of-the art remote sensing methods. Developed as Python plugin for the QGIS geoinformation system, the EnMAP-Box integrates into a well-established, platform-independent, and free-and-open-source software ecosystem to analyze geospatial data. The EnMAP-Box offers advanced functionalities to visualize and process hyper- and multispectral, and multi-temporal remote sensing data, it implements novel spectral libraries concept, and provides easy access to published algorithms from different fields of environmental research. Already been widely used in the past, the EnMAP-Box can now unfold its full potential as first operational EnMAP data became available in 2022.

Code metadata

Current code version	3.12.1
Permanent link to code/repository used for this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-23-00217
Permanent link to reproducible capsule	https://plugins.qgis.org/plugins/enmapboxplugin/version/3.12.1/download/
Legal Code License	GNU GPL-3
Code versioning system used	git
Software code languages, tools, and services used	Python
Compilation requirements, operating environments & dependencies	OS: Windows, macOS, Linux required: PyQGIS, GDAL, NumPy, PyQtGraph (installed with QGIS/EnMAP-Box source code) optional: Scikit-Learn, SciPy, Matplotlib, astropy, opengl, numba
If available Link to developer documentation/manual	https://enmap-box.readthedocs.io
Support email for questions	enmapbox@enmap.org

1. Motivation and significance

Spaceborne Imaging spectroscopy (IS) missions like the Environmental Mapping and Analysis Program (EnMAP) [1,2], the PRecursore IperSpettrale della Missione Applicativa (PRISMA) [3], or the upcoming Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) [4] and NASAs Surface Biology and Geology program (SBG) [5] aim at characterizing the Earth's environment in more detail than is possible with multispectral broadband sensors. The hyperspectral raster images with 200–300 spectral bands, generated by IS sensors, describe the Earth's reflectance, usually from the violet to the short-wave infrared (400–2500 nm). Such datasets allow distinct and spectrally narrow absorption features to be identified and distinguished with high detail [6–8].

IS data is used, e.g., for mapping mineral deposits and soil properties [9,10]; for discriminating detailed vegetation types and variables [11–16]; and to describe land cover [17,18] as well as aquatic ecosystems [19,20]. Moreover, repeated satellite-based acquisitions of IS data will enable the analysis of temporal changes of spectral patterns and underlying processes with previously unknown detail [21].

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RESEARCH

A QGIS -plugin for gully erosion modeling

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Abstract
Gully erosion affects the landscape and human life in many ways, including the destruction of agricultural land and infrastructures, altering the hydraulic potential of soils, as well as water availability. Due to climate change, more areas are expected to be affected by gully erosion in the future, threatening especially low-income agricultural regions. In the past decades, quantitative methods have been proposed to simulate and predict gully erosion at different scales. However, gully erosion is still underrepresented in modern GIS-based modeling and simulation approaches. Therefore, this study aims to develop a QGIS plugin using Python to assess gully erosion dynamics. We explain the preparation of the input data, the modeling procedure based on Sidorchuk's (Sidorchuk A (1999) Dynamic and static models of gully erosion. CATENA 37:401–414.) gully simulation model, and perform a detailed sensitivity analysis of model parameters. The plugin uses topographical data, soil characteristics and discharge information as gully model input. The plugin was tested on a gully network in KwaThunzi, KwaZulu-Natal, South Africa. The results and sensitivity analyses confirm Sidorchuck's earlier observations that the critical runoff velocity is a main controlling parameter in gully erosion evolution, alongside with the slope stability threshold and the soil erodibility coefficient. The implemented QGIS plugin simplifies the gully model setup, the input parameter preparation as well as the post-processing and visualization of modelling results. The results are provided in different data formats to be visualized with different 3D visualization software tools. This enables a comprehensive gully assessment and the derivation of respective coping and mitigation strategies.

Keywords Gully erosion · Temporal modeling · QGIS · OpenSource · Python

Introduction

As noted by de Vente et al. (2013), Vanmaercke et al. (2021) and Borrelli et al. (2022), gully erosion is generally considered to be less studied compared to other soil erosion processes such as splash, sheet, and rill erosion. Nonetheless, gully erosion is responsible for substantial soil loss and sediment production on catchment scale (Valentin et al. 2005, Castillo and Gómez 2016, Märker and Sidorchuk 2003). In general, gully erosion is related to the formation

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Spatial assessment of groundwater potential using Quantum GIS and multi-criteria decision analysis (QGIS-AHP) in the Sawla-Tuna-Kalba district of Ghana

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Remote sensing
Quantum GIS
Recharge

ABSTRACT

Study region: Sawla-Tuna-Kalba (4226 km^2).
Study focus: This study employed QGIS to assess the groundwater potential in the Sawla-Tuna-Kalba district of Ghana with some selected surficial factors while estimating the groundwater recharge from 1981 to 2021.
New hydrological insights: Among the classification algorithms tested, Random Forest (RF) yielded the highest overall accuracy with 93.63% while Support Vector Machine (SVM) and Gaussian Mixture Model (GMM) had 90.22% and 84.73% respectively. From the AHP model, geology had the highest weight of 0.279. It was found that low potential regions comprise 229.53 km^2, moderate zones comprise 1700.62 km^2, high potential zones comprise 2135.04 km^2, and excellent potential areas were found to be 152.14 km^2. The groundwater recharge due to rainfall computed from the Chaturvedi formula indicates that an average of 2.85% of the total annual rainfall goes to groundwater recharge with a variation of ± 0.35 mm. The total recharge for 2021 was found to be 30.18 ± 0.35 mm but between 1981 and 2021 the total recharge was 1191.18 ± 0.35 mm. Also, from the soil analysis, it was found that 56.21% of the study area would allow infiltration. In conclusion, it was observed that the groundwater potential in the study area was high and can be attributed to the recharge and present surficial conditions.

1. Introduction

Groundwater is described as one of the most valuable resources on the earth found within the subsurface, namely; sediments, cracks, fractures, crevices, faults, and many more (Saeedi et al., 2010). These subsurface features can also be referred to as hydrogeological environments or provinces. Groundwater occurs below the water table and usually fills all void spaces (hydrogeological

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Article

Development and Application of a QGIS-Based Model to Estimate Monthly Streamflow

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Abstract: Changes in rainfall pattern and land use have caused considerable impacts on the hydrological behavior of watersheds; a Long-Term Hydrologic Impact Analysis (L-THIA) model has been used to simulate such variations. The L-THIA model defines curve number according to the land use and hydrological soil group before calculating the direct runoff based on the amount of rainfall, making it a convenient method of analysis. Recently, a method was proposed to estimate baseflow using this model, which may be used to estimate the overall streamflow. Given that this model considers the spatial distribution of land use and hydrological soil groups and must use rainfall data at multiple positions, it requires the usage of a geographical information system (GIS). Therefore, a model that estimates streamflow using land use maps, hydrologic soil group maps, and rain gauge station maps in QGIS, a popular GIS software, was developed. This model was tested in 15 watersheds.

Keywords: GIS-based model; hydrologic watershed modeling; streamflow estimation

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1. Introduction

The hydrological behavior of a watershed may vary according to changes in rainfall pattern or land use typically caused by urbanization or industrialization [1,2]. These changes may increase the impermeability in the watershed or alter the frequency or amount of rainfall, which decreases the groundwater recharge; thereby, increasing or changing direct runoff, peak runoff, the potential of downstream flooding, and seasonal variance in hydrological behavior [3]. Moreover, it is difficult to secure water resources as soil water retention decreases in a watershed. In addition, due to a possible increase in nonpoint pollution source (NPS) loads from increased direct runoff from streams, watershed management is necessary to secure water resources and control sources of pollution. During watershed management, rainfall patterns or land use change analyses are performed using hydrological models; the Long-Term Hydrologic Impact Analysis (L-THIA) model has been regularly used since its development in 1994 [4–7].

The L-THIA model was initially developed in a spreadsheet format [4], which was later developed for use in geographic information systems (GISs) [5,6]. An ArcView software-based L-THIA/NPS WWW model was developed in 1999 [7], which reflected various land use conditions. Bhaduri et al. [5] and Lim et al. [7] used the L-THIA/NPS WWW model to analyze direct runoff and nonpoint pollution source load according to changes in land use. During the simulation period from 1973 to 1991, an 18% increase in the impermeable area resulted in an 80% increase in the average annual direct runoff and a 50% increase in the nonpoint pollution source load. Tang et al. [8] applied the L-THIA model from 1973–1997 in Little Eagle Creek, Indiana, United States, to analyze the urban design scenario in the area. Results showed that when the urban area increased by 14% from 1973 to 1983, direct runoff increased by 44%; a 34% increase in the urban area

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Article

Spatiotemporal Change Analysis and Prediction of Future Land Use and Land Cover Changes Using QGIS MOLUSCE Plugin and Remote Sensing Big Data: A Case Study of Linyi, China

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Abstract: Land use and land cover (LULC) change analysis is a systematic technique that aids in the comprehension of physical and non-physical interaction with the natural habitat and the pursuit of environmental sustainability. Research regarding LULC's spatiotemporal changing patterns and the simulation of future scenarios offers a complete view of present and future development possibilities. To simulate the spatiotemporal change transition potential and future LULC simulation, we utilized multi-temporal remotely sensed big data from 1990 to 2020 with a 10-year interval. Independent variables (DEM, slope, and distance from roads) and an integrated CA-ANN methodology within the MOLUSCE plugin of QGIS were utilized. The findings reveal that physical and socioeconomic driving variables have a substantial effect on the patterns of the terrain. In the last three decades, the study area had a significant rise in impervious surface from 10.48% to 26.91%, as well as a minor increase in water from 1.30% to 1.67%. As a result, forest cover decreased from 12.60% to 8.74%, green space decreased from 26.34% to 16.57%, and barren land decreased from 49.28% to 46.11%. Additionally, the predictions (2030–2050) support the increasing trend towards impervious surface at the expense of significant quantities of forest and green space.

Keywords: LULC change; remote sensing; big data; QGIS; impervious surface; prediction; Linyi

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1. Introduction

There is growing use of the term "big data" to characterize the various new data formats being generated by our increasingly digitized, linked, and GNSS-enabled lifestyles. There are enormous and frequently noisy collections of observations that are becoming increasingly geographic and time referenced, and changing the character of data analysis. From a time when all data were spatial, we are moving toward a time-and-space-collected era of spatial-temporal data. GIS research is centered on spatial–temporal relationships [1]. While the importance of closeness in geographical processes is widely established, its relevance in temporal processes is far more ambiguous. Numerous processes, however, exhibit distinct periodicities that require synchronization between the phase of the process being viewed and the time of observations, rather than just temporal proximity [2]. Identifying temporal patterns needs an informed treatment of time series to guarantee that the phase of observation (data) corresponds to the process's frequency. Remote sensing data are enormous, with a significant deal of variety in addition to volume, from what is captured by sensors to how data are presented to users, with variations in pixel size, sampled spectral regions, revisit rate, and so on. Due to huge volume and variety, remote sensing data are considered "remote sensing big data" [3–5]. New analytical methodologies for large remote sensing data sets have been advocated, in part to address the pervasive challenge and need

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ORIGINAL PAPER

Climatology of waterspouts in the Balearic Islands (1989–2020)

Jaume Reynés Vega[1] · M. Carmen Moreno-García[2] · Francisco Pastor Guzman[3]

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Abstract

The article analyses the waterspouts recorded in the Balearic Islands (Spain) between 1989 and 2020. The extensive database used includes 234 waterspout events, which we analysed to establish their annual, monthly, seasonal and weekly spatial, temporal and hourly distribution. The autumn months account for 65% of all the waterspout events, with the highest frequency seen in September. They occur most frequently between 8:00 and 10:00 in the morning. We carried out a synoptic classification of the days on which waterspouts were recorded, observing that a synoptic trough pattern at 500 hPa over the Iberian Peninsula, which generates a south-westerly flow over the area under study, was the most conducive waterspout-creating condition (present in 25.3% of the events). Their relationship with the sea surface temperature was also analysed, revealing a higher frequency of waterspouts with higher temperature values, particularly between 23 and 26 °C. Finally, we examined the frequency of waterspouts in relation to the daily Western Mediterranean Oscillation regional teleconnection pattern index values, finding that waterspouts were more common on days when the indices were closer to 0.

Keywords Waterspouts · Temporal distribution · Synoptic classification · Sea surface temperature (SST) · Teleconnection pattern in the Western Mediterranean (WeMO)

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A2. GVSIG

CG9. A2

1. Descripción

gvGIS es un proyecto de desarrollo de software para Sistema de Información Geográfica basado en software libre. Este proyecto fue inicialmente impulsado, en 2004, por el gobierno regional de la Comunidad Valenciana, de hecho, gvSIG abrevia la denominación *Generalitat Valenciana Sistema de Información Geográfica*. Desde 2010 la gestión y el mantenimiento del catálogo tecnológico gvSIG es llevado a cabo por la Asociación gvSIG. Esta asociación engloba tanto entidades empresariales como no empresariales (universidades, administraciones públicas, institutos geográficos, etc.)

gvSIG Desktop es un software integrador, capaz de trabajar con información de cualquier tipo u origen, tanto en formato ráster como vectorial, y comparte algunas otras características con JUMP como su arquitectura modular o su carácter multiplataforma. Además, permite trabajar con formatos de otros programas como Autocad, Microstation o ArcView, de acuerdo con los parámetros de la *OGC* (Open Geospatial Consortium) que regula los estándares abiertos e interoperables de los Sistemas de Información Geográfica. Las herramientas que implementa permiten una gran precisión en edición cartográfica, incluye funciones avanzadas para usos en teledetección, morfometría e hidrología, y otras funciones básicas como diseño de impresión y soporte de los formatos más populares, tanto vectoriales como de imágenes.

gvSIG Desktop es una aplicación de la que ya existen varias versiones, y aunque su funcionalidad está prácticamente cubierta y se ha convertido en una referencia dentro de las tecnologías SIG, continúa actualmente en fase de desarrollo y perfeccionamiento, siempre bajo los principios de compartir y elaborar.

Las principales investigaciones en las que se ha usado gvSIG recientemente son Chigbu et al., 2021; Gutiérrez et al., 2022; García-Ayllón et al., 2022; Juan et al., 2022; Rodríguez y Alonso, 2002;

Schiaffini, 2022 y Vázquez-Palacios y Tovar-Cabañas 2022.

2. Características técnicas

Programa	gvGIS desktop		
Versión	2.5.1	Año	2020
Tipología	Sistemas de Información Geográfica		
Capacidades del programa	gvSIG es un Sistema de Información Geográfica en software libre, es decir, una aplicación geográfica orientada a representar, editar, analizar y gestionar información desde el punto de vista de las relaciones espaciales. gvSIG permite representar datos espacialmente (en formato ráster o vectorial, así como bases de datos y servicios remotos) en los distintos sistemas de coordenadas. Además, dispone de herramientas para diseñar mapas con opciones de impresión y exportación. También permite editar datos alfanuméricos y cartográficos, así como realizar análisis espaciales con más de 300 geoprocesos disponibles. Por último, gvSIG permite ampliar su funcionalidad mediante un módulo de scripting sobre Python.		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
	macOS X (64 bits): versión anterior (2.4)		
Tipo de sistema (arquitectura)	32 y 64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	Open Source Geospatial Foundation (OSGeo) / Asociación gvSIG		
Web	https://www.gvgis.com		

3. Ejemplos de trabajos científicos

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Article

Fit-for-Purpose Land Administration from Theory to Practice: Three Demonstrative Case Studies of Local Land Administration Initiatives in Africa

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Abstract: Land is a critical factor of production for improving the living conditions of people everywhere. The search for tools (or approaches or strategies or methods) for ensuring that land challenges are resolved in ways that quickly respond to local realities is what led to the development of the fit-for-purpose land administration. This article provides evidence that the fit-for-purpose land administration—as a land-based instrument for development—represents an unprecedented opportunity to provide tenure security in Africa. The article presents case studies from three sub-Saharan African countries on local-level experiences in the applications of fit-for-purpose guidelines as an enabler for engaging in tenure security generating activities in communities. These case studies, drawn from Ghana, Kenya, and Namibia, are based on hands-on local land administration projects that demonstrate how the features of the fit-for-purpose guideline were adopted. Two of the case studies are based on demonstrative projects directly conducted by the researchers (Ghana and Kenya), while the other (Namibia) is based on their engagement in an institutional project in which the Global Land Tool Network (GLTN) and other local partners were involved. This work is relevant because it paves a path for land administration practitioners to identify the core features necessary for land-based projects.

Keywords: customary tenure; fit-for-purpose; land administration; land inventory; land management; land tenure; mobile-based applications; pro-poor; land surveying; tenure security

1. Introduction

Access to land means gaining physical availability to land and making decisions on its use or exercise of the rights embedded therein [1,2]. Access to land is fundamental for creating livelihood opportunities for many people living in developing countries [3,4]. It is also a determinant factor on how land is put into sustainable use countries [5,6]. Important to land access, is the issue of land tenure security. It is impossible for individuals without land tenure security—i.e., the rights individuals and groups have to effective protection by the state against forced eviction—to take advantage of opportunities to improve their living standards [7–9]. Land tenure security is linked to ending poverty in all its forms everywhere. The lack of secure tenure "creates significant instabilities and inequalities in society and severely limits citizens' ability to participate in social and economic development" and "also undermines better land use and environmental stewardship and deters responsible private investment, due to the associated land risk" [10] (p. 2). The role of land tenure

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Article

Analysis of the Spatial Correlation between Port Areas Configuration and Alterations of the Coastal Shoreline: A Multidisciplinary Approach Using Spatiotemporal GIS Indicators

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Abstract: Transformations that occur in the coastal territory often have an important link with the construction of port infrastructures, although establishing a direct correlation between causes and effects is rarely straightforward as they are phenomena that emerge over decades. Moreover, this phenomenon is fundamentally observed in developed countries, where we also find the added difficulty that a high number of variables intervene since the coast is usually an environment that is strongly anthropized by human action whilst being an important tourist asset. This study analyzes, from a different perspective than traditional coastal engineering approaches, the existing correlation between the construction of various marinas and coastal infrastructures along the southeast of the Spanish Mediterranean coast. The existing geostatistical correlation between the configuration of port areas and the coastal and socioeconomic impacts that occurred during the decades following the construction of these infrastructures was evaluated using spatiotemporal GIS indicators. The results obtained show that there are different patterns of behavior in the impact generated by port infrastructures depending on the spatial configuration of their boundary conditions, beyond the behavior of sedimentary dynamics usually studied in civil engineering.

Keywords: coastal shoreline; Spanish Mediterranean coast; Mar Menor; port infrastructures; beach management; geostatistical analysis

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1. Introduction

Coastal urban areas are usually the most anthropized spaces on the planet in all countries. Infrastructures located on them (ports, but also breakwaters, dredging, landfills reclaimed from the sea, etc.) have traditionally been a source of transformation of their land uses and of long-term alteration of the shoreline [1,2]. Coastal impacts such as the regression or the growth of the beach line are well-known derivatives associated with the construction of this type of infrastructure [3]. However, there is also a varied catalog of anthropic impacts, such as the generation of mud on the coast, the formation of tombolos and hemitombolos, erosion, and the development of different kinds of diffuse anthropization phenomena associated with the growth of coastal urban areas due to the effect caused by the development of a coastal infrastructure [4,5].

The analysis of anthropic impacts on the coastline has been widely studied from the point of view of the generation of port infrastructures [6–8]. Direct and indirect, deterministic and semi-probabilistic, etc. approaches to the dynamics of the coast are usually used [9,10]. These approaches focus their analysis of the impacts on sedimentary dynamics on models developed from climatological or endogenous variables of the design of the port infrastructure itself, such as fetch, the statistical height of the design wave, the bathymetry, or the orientation of the dikes [11].

infrastructures

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Article

Multi-Criteria Methodology for the Location of Photovoltaic Solar Energy Production Facilities in Tenerife (Spain)

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Abstract: This paper presents a multi-criteria methodology for the detection of optimal locations for solar photovoltaic installations connected to the electrical grid. The proposed methodology has been applied to the island of Tenerife, as it is one of the territories in Spain with the greatest solar potential. This methodology integrates an Aptitude Model (which covers variables such as connections to the electrical grid, accessibility, cloudiness, solar irradiation and slope) together with an Impact Model (which considers variables such as landscape vulnerability, land use and hydrology). Each one of the variables considered has been transformed into standardized decision criteria, which have been weighted by means of Saaty's pair method, having also assigned them relative weights by means of expert consultation. The integration of both Models in a Hosting Capacity Model makes it possible to consider urban and environmental constraints in different possible scenarios. Finally, the Hosting Capacity Model generated is implemented through a Geographic Information System (GIS) on the island of Tenerife, so that it has been possible to detect the optimum locations for each municipality and region.

Keywords: photovoltaic solar energy; territorial planning; Geographic Information System (GIS); Hosting Capacity Model

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1. Introduction

In the last 10 years, the photovoltaic sector in Spain has been immersed in a social upheaval, motivated mainly by the reduction of the costs of the installations, and by the support of certain regulations [1,2]. Ley 24/2013 of 26 December [3] on the Electricity Sector generally established the granting of a specific remuneration system through a competitive tendering procedure. However, an additional provision of this law established an investment incentive for the reduction of generation costs with the aim of replacing conventional generation by renewable sources in the island territories. In the Canary Islands, photovoltaic installations under RD 413/2014 [4] are a good alternative for electricity generation due to investment incentives, economies of scale and the reduction in the price of solar panels [5–7]. Therefore, this type of facility is currently profitable as long as it is located in an area with high solar radiation and is close to a connection point to the electricity grid [8,9], despite the fact that tariff-based remuneration and the elimination of premiums for photovoltaic electricity production will slow down the expansion of the sector [10,11].

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Original Research

Bayesian and network models with covariate effects for predicting heating energy demand

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ABSTRACT

The spatial effect is an element presented in many geostatistical works and it should be incorporated into studies regarding the heating energy demand of residential building stocks. The most common approaches have been made by simple descriptive statistics or using analyses by Markov random fields. In this work, we propose two different methods. First, the Stochastic Partial Differential Equation with the Integrated Nested Laplace Approximation to model the variable heating energy demand in Castellón de la Plana, Spain also considering covariates and the spatial effect. Second, simulated street networks for analysing data. We describe and take advantage of the Bayesian methodology in the modelling process in all the scenarios, including covariates and the possibility of creating a simulated street network with the data for the modelling issue. Our results show that the spatial location of the building is a crucial element to study the heating energy demand using both methodologies.

1. Introduction

Heating energy demand (ED_h) has an impact on prices and is a growing concern about environmental problems and global warming. ED_h was recently incorporated into the energy production agenda (Royston et al., 2018). The study of factors associated to changes in ED_h is complex due to its association with other variables such as building block geometry and spatial distribution of building units in urban areas, characteristics of energy distribution networks, morphology of the urban layout and weather-related variables, amongst others.

Office and residential buildings account for a significant proportion of energy demand and use. Residential energy use, mostly for heating, is an important fraction of the total energy use in Spain and energy efficiency action plans have been in operation in Spain since 2014 (IDAE 2016). For these plans to work properly, it is important to monitor the demand and to predict future trends. ED_h shows spatial variability because the spatial distribution of households and different kind of industries is not completely random. This is mainly because the presence of short scale heterogeneity in building and size. In consequence it is expected that trends in energy demand will also show spatial variability. Therefore, the inclusion of spatial heterogeneity in the modelling process of variables showing spatial variation improves model quality and gives the correct power in statistical tests (Cressie, 1993). This is important because municipalities can use the resulting models and the graphical representation of the resulting maps in planning actions for a better use of energy.

In this work, we present the results of the spatial analysis and modelling of the ED_h in the residential building zone of Castellón de la Plana, Spain, and its association to urban and building characteristics (Braulio-Gonzalo et al., 2016). We selected the city of Castellón de la Plana, Spain, because it is a medium-sized city, and it has been chosen before to implement a bottom-up-based model to predict ED_h.

We consider models in the class of the Generalized Linear Mixed Models (GLMM), a class that became popular in the late 80's and early 90's to analyse and predict different kinds of response variables with linear association to random and fixed factors (Breslow and Clayton, 1993). In our study we use information on several covariates related to urban and building characteristics at the building level. Our study only covers the wintertime, when the need for heat increases EDh and most of the buildings' global energy use (Eurostat 2018).

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EL MAPA SANITARIO, UNA HERRAMIENTA PARA LA PLANIFICACIÓN Y ORDENACIÓN EN SALUD:
EL CASO DE MAURITANIA

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Santiago Alonso-Pardo[2]

RESUMEN – Los llamados mapas sanitarios son un instrumento para el fomento, la democratización y el derecho a la información pública en salud. Asimismo, han sido desde épocas anteriores una herramienta que permite contextualizar y focalizar mejor las desigualdades, del sector de la salud pública y de otros sectores afines. Este artículo tiene por objetivo explicar la elaboración del mapa sanitario de Mauritania, y su valor en la planificación y reordenación de la oferta de servicios de salud en todos los niveles de la pirámide sanitaria del país para dar respuesta a las crecientes peticiones sobre información generadas por varios organismos, pero principalmente, del sector de salud mauritano. Se presenta la metodología utilizada para elaborar de forma participativa un mapa de activos para la salud en un país africano concreto. Se utiliza la técnica de la encuesta como procedimiento de investigación, ya que permite obtener y elaborar datos de modo rápido y eficaz. Los sistemas de información geográfica constituyeron un apoyo importante al trabajo. El mapa sanitario elaborado fue una herramienta fundamental para la gestión y ordenación del territorio en cuestión de planificación sanitaria para los cinco años siguientes, ha permitido ordenar los recursos sanitarios para conseguir una oferta de servicios más adecuada a las necesidades de la población, evitando duplicidades asistenciales, a la vez que se convierte en un potente instrumento de apoyo a la toma de decisiones. Este conocimiento territorial permitió y posibilitó la realización posterior de Planes de Desarrollo Sanitario en las regiones con mayores desigualdades en salud.

Palabras clave: Mapa sanitario; inequidad en salud; planificación en salud; análisis espacial; Mauritania.

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Distribution patterns of South American mustelids (Carnivora: Mustelidae)

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Climate has long been recognized as one of the main determinants of the geographical distribution of species. Variations associated with primary productivity in temperature, rainfall, and photoperiod can affect survival and reproduction, affecting the peripheries of geographical distributions. The importance of graphical visualization of these distributions lies in conservation, management, and environmental research. With respect to the South American species of mustelids, 37% are threatened according to the IUCN Red List, and the limits of distributions and their determinants are poorly known for the majority of species. Here, complete and updated databases and maps of geographical and temporal distribution are presented for the 12 species of mustelids inhabiting South America. Museum specimens and recorded localities were gathered based on an online search. Geographic limits of distributions were assessed, as were environmental values for all localities. Comparison with IUCN maps was undertaken to determine the need for updating. Finally, sympatry and syntopy among species analyzed were examined using Geographic Information Systems. The most complete and updated database of geographic distributions of South American mustelids to date was assembled for all species, encompassing 9,826 localities. New areas with recorded localities not present in IUCN maps were documented in many species, indicating the need to update current maps for conservation efforts. Areas of sympatry and syntopy were found among many species, indicating that patterns of coexistence between them are not well known. This study will serve as a framework for ensuing efforts in species distribution modeling, conservation decisions, and field studies, among others.

Key words: climate, conservation, Neotropical region, niche, otters, weasels

El clima ha sido reconocido durante mucho tiempo como el mayor determinante de la distribución geográfica de las especies. Las variaciones de temperatura, precipitaciones, y fotoperíodo asociados a la productividad primaria pueden afectar la supervivencia y reproducción, marcando los límites de las distribuciones geográficas de las especies. Las visualizaciones gráficas de las distribuciones son vitales para la conservación, manejo y estudios ambientales. De la fauna de mustélidos sudamericana, el 37% se encuentra en una de las categorías de amenaza de la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza (UICN), mientras que los límites de distribución y sus determinantes son desconocidos para la mayoría de estas especies amenazadas. En este estudio, se presentan bases de datos y mapas actualizados de la distribución geográfica y temporal de las 12 especies de mustélidos presentes en Sudamérica. Se utilizaron localidades provenientes de especímenes de museos junto a una extensa búsqueda de registros de mustélidos online. Se evaluaron los límites geográficos de distribución y los valores de las variables ambientales para todas las localidades. Se realizaron comparaciones con los mapas de la UICN para analizar si una actualización del mapa de distribución sería necesaria. Por último, se evaluó la presencia de simpatría y sintopía de las especies analizadas utilizando Sistemas de Información Geográfica. Se colectó un total de 9.826 localidades para todas las especies de mustélidos, representando así la base de datos más actualizada de la distribución geográfica de este grupo en América del Sur. Se identificaron áreas con registros

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Natural and cultural longevity zones from an anthropological and geographical viewpoint

Felipe R. Vázquez-Palacios[1] · Rodrigo Tovar-Cabañas[2]

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Abstract

There are natural and cultural variables that have an impact on the longevity of older adults. In the case of the former, it is necessary to know and territorialize them, and in the case of the latter, it is necessary to understand them through the analysis of customs and lifestyles. The zones of natural longevity, for this analysis, are those in which low levels of ionizing and ultraviolet radiation converge, as well as the presence of water containing deuterium oxide among its components. To address the cultural longevity zones, an ethnography was carried out in which it was observed that both the consumption of heavy water and the lifestyles generated by the production of coffee and sugar cane prolong life and good old age in the town of El Espinal, municipality of Naolinco, Veracruz.

Keywords Geography · Ethnography · Natural longevity · Cultural Longevity · Radiation · Blue zones

Introduction

Studies on the society-nature relationship present a diversity of definitions, however, there are two tendencies: the first uses the term 'culture' as separate from politics, the environment, the economy, etc., while the second uses the term 'culture' as a way

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A3. GRASS

CG9. A3

1. Descripción

Grass GIS es un software SIG bajo licencia GPL, es decir, libre. Puede soportar información espacial tanto ráster como vectorial y posee herramientas de procesado digital de imágenes. Este programa está ideado para la gestión y análisis de datos geoespaciales, procesamiento digital de imágenes, producción de mapas y gráficos, modelización espacial y visualización.

Este programa fue desarrollado en sus inicios, en 1982, por el Cuerpo de Ingenieros del Laboratorio de Investigación de Ingeniería de la Construcción del Ejército de Estados Unidos (USA-CERL) como herramienta para la supervisión y gestión medioambiental de los territorios bajo administración del Departamento de Defensa. En 1991 este software se pone a disposición pública a través de internet, creciendo su popularidad en universidades, empresas y agencias gubernamentales. En 1997 se hace cargo de du desarrollo la Universidad de Baylor y en 1999, con su versión 5.0, se libera el código bajo licencia GNU.

Desde la versión 7.0 de Grass GIS ofrece mejoras en el ámbito de bases de datos voluminosas, trabajos vectoriales en 2 y 3 dimensiones y nuevas opciones en el análisis de redes vectoriales entre otras novedades.

Actualmente se puede utilizar su funcionalidad dentro de QGIS, como un complemento del núcleo.

Las principales investigaciones en las que se ha usado Grass GIS recientemente son Amatulli et al. 2022; Pareeth y Karimi, 2023; Petrasova et al., 2017; Sabatiani y Fares, 2023; Ruxinko y Horáčková, 2022; Wegmann et al., 2018 y White at al., 2023.

2. Características técnicas

Programa	GRASS GIS		
Versión	8.2.1	Año	2023
Tipología	Sistemas de Información Geográfica		
Capacidades del programa	GRASS GIS (Geographic Resources Analysis Support System) ofrece potentes motores de procesamiento ráster, vectorial y geoespacial en un único paquete de software integrado. Incluye herramientas para el modelado de terrenos y ecosistemas, hidrología, visualización de datos ráster y vectoriales, gestión y análisis de datos geoespaciales y procesamiento de imágenes satelitales y aéreas. Viene con un marco temporal para el procesamiento avanzado de series de tiempo y una API de Python para una programación geoespacial rápida. GRASS GIS se ha optimizado para el rendimiento y el análisis de grandes datos geoespaciales. Funcionalidades de este software se emplean en otros SIG como QGIS como parte de sus complementos.		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	32 y 64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	Open Source Geospatial Foundation (OSGeo) / GRASS GIS development team		
Web	https://grass.osgeo.org/		

3. Ejemplos de trabajos científicos

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Open Access Earth System Science Data

Hydrography90m: a new high-resolution global hydrographic dataset

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Abstract. The geographic distribution of streams and rivers drives a multitude of patterns and processes in hydrology, geomorphology, geography, and ecology. Therefore, a hydrographic network that accurately delineates both small streams and large rivers, along with their topographic and topological properties, with equal precision would be indispensable in the earth sciences. Currently, available global hydrographies do not feature small headwater streams in great detail. However, these headwaters are vital because they are estimated to contribute to more than 70 % of overall stream length. We aimed to fill this gap by using the MERIT Hydro digital elevation model at 3 arcsec (~ 90 m at the Equator) to derive a globally seamless, standardised hydrographic network, the "Hydrography90m", with corresponding stream topographic and topological information. A central feature of the network is the minimal upstream contributing area, i.e. flow accumulation, of 0.05 km^2 (or 5 ha) to initiate a stream channel, which allowed us to extract headwater stream channels in great detail. By employing a suite of GRASS GIS hydrological modules, we calculated the range-wide upstream flow accumulation and flow direction to delineate a total of 1.6 million drainage basins and extracted globally a total of 726 million unique stream segments with their corresponding sub-catchments. In addition, we computed stream topographic variables comprising stream slope, gradient, length, and curvature attributes as well as stream topological variables to allow for network routing and various stream order classifications. We validated the spatial accuracy and flow accumulation of Hydrography90m against NHDPlus HR, an independent, national high-resolution hydrographic network dataset of the United States. Our validation shows that the newly developed Hydrography90m has the highest spatial precision and contains more headwater stream channels compared to three other global hydrographic datasets. This comprehensive approach provides a vital and long-overdue baseline for assessing actual streamflow in headwaters and opens new research avenues for high-resolution studies of surface water worldwide. Hydrography90m thus offers significant potential to facilitate the assessment of freshwater quantity and quality, inundation risk, biodiversity, conservation, and resource management objectives in a globally comprehensive and standardised manner. The Hydrography90m layers are available at https://doi.org/10.18728/igb-fred-762.1 (Amatulli et al., 2022a), and while they can be used directly in standard GIS applications, we recommend the

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Evapotranspiration estimation using Surface Energy Balance Model and medium resolution satellite data: An operational approach for continuous monitoring

S. Pareeth✉ & P. Karimi

Monitoring spatial and temporal trends of water use is of utmost importance to ensure water and food security in river basins that are challenged by water scarcity and climate change induced abnormal weather patterns. To quantify water consumption by the agriculture sector, continuous monitoring is required over different spatial scales ranging from field (< 1 ha) to basin. The demand driven requirement of covering large areas yet providing spatially distributed information makes the use of in-situ measurement devices unfeasible. Earth observation satellites and remote sensing techniques offer an effective alternative in estimating the consumptive use of water (Actual EvapoTranspiration (ET_a) fluxes) by using periodic observations from the visible and infrared spectral region. Optical satellite data, however, is often hindered by noises due to cloud cover, cloud shadow, aerosols and other satellite related issues such as Scan Line Corrector (SLC) failure in Landsat 7 breaking the continuity of temporal observations. These gaps have to be statistically filled in order to compute aggregated seasonal and annual estimates of ET_a. In this paper, we introduce an approach to develop a gap-filled multi-year monthly ET_a maps at medium spatial resolution of 30 m. The method includes two major steps: (i) estimation of ET_a using the python based implementation of surface energy balance model called PySEBAL and (ii) temporal interpolation using Locally Weighted Regression (LWR) model followed by spline based spatial interpolation to fill the gaps over time and space. The approach is applied to a large endorheic Lake Urmia Basin (LUB) basin with a surface area of ~ 52,970 km^2 in Iran for the years 2013–2015 using Landsat 7 and 8 satellite data. The results show that the implemented gap filling approach could reconstruct the monthly ET_a dynamics over different agriculture land use types, while retaining the high spatial variability. A comparison with a similar dataset from FAO WaPOR reported a very high correlation with R^2 of 0.93. The study demonstrates the applicability of this approach to a larger basin which is extendible and reproducible to other geographical areas.

Water scarcity is one of the most critical global issues of the twenty-first century which has affected the daily livelihood of millions. An estimated forty percent of the global population are experiencing water scarcity at different magnitudes[1,2]. In Asia and the Middle East region, water scarcity is mainly driven by climate change, improper water use, and growing population[3]. Many studies have reported a rapid decrease in the level of groundwater table in the semi-arid regions of Asia and the Middle East mainly due to the overuse of water to meet irrigation needs[4–6]. Therefore, there is a great need to establish monitoring systems to facilitate timely interventions ensuring sustainable management of land and water resources. One of the Sustainable Development Goal (SDG)—SDG 6 targets to substantially reduce the number of people suffering from water scarcity by improving water use efficiency by the year 2030[7]. The biggest share of water (around 70%) in Asia is allocated

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Open Geospatial Data, Software and Standards

ORIGINAL ARTICLE Open Access

Fusion of high-resolution DEMs for water flow modeling

Anna Petrasova[1,2*], Helena Mitasova[1,2], Vaclav Petras[1,2] and Justyna Jeziorska[1,2,3]

Abstract

Background: New technologies for terrain reconstruction have increased the availability of topographic data at a broad range of resolutions and spatial extents. The existing digital elevation models (DEMs) can now be updated at a low cost in selected study areas with newer, often higher resolution data using unmanned aerial systems (UAS) or terrestrial sensors. However, differences in spatial coverage and levels of detail often create discontinuities along the newly mapped area boundaries and subsequently lead to artifacts in results of DEM analyses or models of landscape processes.

Methods: To generate a seamless updated DEM, we propose a generalized approach to DEM fusion with a smooth transition while preserving important topographic features. The transition is controlled by distance-based weighted averaging along the DEMs' blending overlap with spatially variable width based on elevation differences.

Results: We demonstrate the method on two case studies exploring the effects of DEM fusion on water flow modeling in the context of precision agriculture. In the first case study, we update a lidar-based DEM with a fused set of two digital surface models (DSMs) derived from imagery acquired by UAS. In the second application, developed for a tangible geospatial interface, we fuse a georeferenced, physical sand model continuously scanned by a Kinect sensor with a lidar-based DEM of the surrounding watershed in order to computationally simulate and test methods for controlling storm water flow.

Conclusions: The results of our experiments demonstrate the importance of seamless, robust fusion for realistic simulation of water flow patterns using multiple high-resolution DEMs.

Keywords: UAS, UAV, Lidar, Kinect, GRASS GIS

Background

High-quality digital elevation models (DEM) provide essential data for research in many scientific disciplines as well as for numerous practical applications. Today, DEMs can be generated by a variety of remote sensing techniques including conventional and Structure-from-Motion photogrammetry (SfM), radar interferometry, lidar, or short-range 3D cameras [1, 2]. The different remote sensing sensors, platforms and DEM reconstruction algorithms result in DEM products with different properties in terms of spatial extent, resolution, accuracy, survey date, and whether they represent digital surface model (DSM) or bare ground. To address inhomogenity of available DEM products, several methods of fusing DEMs have been developed to obtain a complete DEM coverage with improved quality. Fusion approaches vary from simple techniques, such as weighted averaging of input DEMs based on height error maps [3], or terrain derivatives [4, 5], to more complex techniques involving the use of sparse representations [6], frequency domain filtering [7], slope-based Markov random field regularization [8], or k-means clustering [9].

In these cases the fusion method combines several overlapping DEMs in order to obtain a higher quality DEM with homogenous error characteristics. However, these methods are typically not suitable for cases when one DEM needs to be updated with a newer or a higher resolution one within a specific subregion. Simple merging

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forests

MDPI

Article

Spatial Prioritization of Ecosystem Services for Land Conservation: The Case Study of Central Italy

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Abstract: Ecosystem services delivered by natural ecosystems are increasingly important for climate change adaptation and mitigation and play a huge role in biodiversity conservation. For this reason, the EU has the ambitious goal of protecting at least 30% of land by 2030. Member states are called to improve and expand the network of protected areas within the next few years; to do so, scientific studies aimed at identifying areas with high ecological value, as well as at defining best management practices, are highly needed. In this study, we used the InVEST suite of models to spatially assess three regulating ecosystem services, that is, carbon storage, seasonal water yield, and urban flood risk mitigation in three administrative regions of central Italy. Using overlay analysis, we found areas with the highest delivery in each of the considered ESs; based on these findings, we eventually proposed four new protected areas, which combine for 888 km^2, that is, 2.73% of the study area. Interestingly, each of the newly proposed protected areas has somehow been discussed and hypothesized by stakeholders, but only one is presumably going to be part of the national network of protected areas within the next years. Hopefully, by prioritizing areas according to the production of ecosystem services, this study can be intended as a step towards the systematic inclusion of ecosystem services studies for enhancing the network of areas under national protection schemes and achieving the goal of protecting at least 30% of land in Europe by 2030.

Keywords: protected areas; regulating ecosystem services; spatial analysis; land conservation

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1. Introduction

Protecting natural capital has become increasingly important over the last years in order to mitigate environmental and social issues related to climate change [1,2]. Indeed, through the delivery of ecosystem services (ESs), nature can sequester and store CO_2, remove air pollutants from the atmosphere, prevent floods caused by extreme precipitation events, lower the air temperature during heatwaves, host remarkable biodiversity, and provide space for recreational and cultural activities [3–7]. ESs may also boost social development by creating economic opportunities such as ecotourism [8].

The European Commission (EC) has widely acknowledged the role of nature in improving human health and well-being, recognizing that nature-based solutions (NBSs), which include the protection of natural ecosystems, are essential for climate change adaptation [9]. In the EU Biodiversity Strategy for 2030, it is stated that at least 30% of land should be protected by 2030, one-third of which under strict protection, which means a minimum of an extra 4% compared to today's levels. Plus, efforts should be made to ensure high connectivity amongst protected areas, to create a coherent trans-European Nature Network [9]. The EC has also recently proposed the Nature Restoration Law, a pioneering proposal that aims at preventing ecosystems' collapse and the negative impacts exerted by climate change through numerous restoration measures. Protected areas are indeed

GEOGRAPHIA CASSOVIENSIS XVI 2/2022

Flash flood simulation in the urbanised catchment: a case study of Bratislava-Karlova Ves

Adam RUSINKO, Šárka HORÁČKOVÁ

Abstract: *Flash floods are a dangerous phenomenon that generally affects small drainage basins. They are primarily initiated in the upper parts of the slopes, but their damaging effects are manifested mostly in residential areas, where naturally flowing streams were removed from the surface to the underground artificial channels. Therefore, there are no precise data about stream water levels available and only using surface runoff modelling is possible to simulate what happened during flash floods. Karlova Ves (Bratislava City District), formerly a small viniculture village, was threatened by floods (most probably including pluvial type) in history. In this paper, we used GRASS GIS tool r.sim.water to simulate the surface runoff of a flash flood that occurred in summer 2014 in the catchment of Čierny potok. The flood on 23 August 2014 was reported to have the highest rainfall per hour ~40 mm during the time of local meteorological measurements. The current orthophotomap was used to classify the land cover classes, which were assigned the value of the Manning's roughness coefficient and infiltration rate. The topography was expressed by DTM from high-resolution LiDAR data. Our preliminary results indicate that land cover and land use are the essential factors that influence the initiation of flash floods, although the main driver of lower infiltration and change in flow direction is caused by urbanisation and a high proportion of impervious areas. Simulation showed that during 60 minutes of extreme rainfall (40 mm/hr) a surface runoff can reach a depth of water up to two meters in terrain depressions by a maximum discharge of 25 cubic meters. The revitalisation of natural urban areas by increasing vegetation cover in areas prone to flash floods and accumulation of water during higher rainfalls helps to prevent the damage caused by floods.*

Keywords *Čierny potok stream, flash flood, GRASS GIS, LiDAR, CORINE Land Cover, Bratislava*

Introduction

Flash floods are worldwide one of the most dangerous natural global hazards because they often cause human casualties and significant material damage (Boardman et al. 2003, Karagiorgos et al. 2016, Miller and Hutchins 2017). These types of floods occur in several European countries (Gaume et al. 2009) including Slovakia (Solín and Cebecauer 1998, Stankoviansky 2002, 2009, Urbánek 2005, Stankoviansky and Frandofer 2012). The terminology used is not uniform, with several synonyms or different definitions describing flood-type as pluvial floods or muddy floods (Gaume et al. 2009, Johnson and Priest 2008). While the classification is specific for smaller streams or dry valleys without permanent water levels where episodic water flow-induces gully formations in extreme rainfall (Urbánek 2005), it differs for sediments contained in the flood-waters.

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APPLICATION

Methods in Ecology and Evolution BRITISH ECOLOGICAL SOCIETY

r.pi: A GRASS GIS package for semi-automatic spatial pattern analysis of remotely sensed land cover data

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Abstract

1. Analysing the changing spatial patterns of landscapes due to climate change or anthropogenic impact is important for various disciplines. Land cover change and its resulting modification of spatial patterns in the landscape influence various geographical or ecological parameters. Changing formerly continuous into discontinuous ecosystems due to land cover conversion causes isolated fragments in the landscape. Maintaining the connectivity of a fragmented landscape is relevant for, e.g. in nutrient cycle, water-runoff or species population persistence.
2. Satellite imagery derived land cover can be used to analyse continuously the changing spatial arrangement of land cover types. However, analyses are computer intensive and require robust and efficient processing routines.
3. We developed a patch-based spatial analysis system (*r.pi*) integrated natively into a Free and Open Source GIS (GRASS GIS) to be able to analyse large amounts of satellite derived land cover data in a semi-automatic manner, and to ensure high reproducibility and robustness.
4. Various established and newly developed indices for spatial pattern analysis are provided in this program, to derive further meaningful information like spatial configuration, patch irreplaceability or connectivity of fragments based on a dispersal model approach.

KEYWORDS
connectivity, GIS, landscape fragmentation, patch irreplaceability, remote sensing, spatial ecology

1 | INTRODUCTION

In the last decades, a global decrease of unaltered and undisturbed land cover has been observed (Hansen et al., 2013; Laurance et al., 2002; Margono, Potapov, Turubanova, Stolle, & Hansen, 2014; Mayaux et al., 2005). Human activities result in habitat fragmentation, degradation or complete habitat loss. Fragmentation is regarded as human induced increase in numbers, decreased connectivity or decreased size of fragments (Fahrig, 2003) and is a key focus of quantitative landscape ecology (Gustafson, 1998; O'Neill et al., 1988; Turner, 1989). Downstream effects include changes to the nutrient and water cycles or the disruption of species migration, and hence, a diminished chemical and biotic exchange eventually leading to the depletion of landscapes with respect to their environmental conditions (Collinge, 1996; Fischer & Lindenmayer, 2007; Saunders, Hobbs, & Margules, 1991). Hence, when analysing connectivity, it is important to take the surrounding landscape into account in order to derive information concerning landscape friction which influences the functional connectivity between fragments (Debinski, 2006; Ricketts, 2001).

Monitoring of land cover changes, such as fragmentation, is increasingly accomplished using remote sensing data with increasing focus on high spatial and temporal resolution satellite imagery (Achard et al., 2007).

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An open-source platform for geospatial participatory modeling in the cloud

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ABSTRACT

Participatory modeling facilitates the co-production of knowledge and action by engaging stakeholders in research. However, the spatial dimensions of socio-environmental systems and decision-making are challenging to incorporate in participatory models, as developing interactive geospatial models requires specialized knowledge. Yet, many of society's most pressing and complex socio-environmental problems require participatory modeling that is geospatial. Existing interactive online applications have broadened the audiences who can engage with geospatial models, but often do not provide a robust framework for interactive model development. Here, we develop an open-source platform, OpenPlains, to address barriers to participation in geospatial modeling by enabling researchers to develop interactive models that remove barriers to data aggregation and user engagement. OpenPlains consists of six new open-source libraries: OpenPlains, django-actina, grass-js-client, react-openplains, react-ol, and openplains-cli. We demonstrate OpenPlains through two web applications that work anywhere in the contiguous United States: a spatial–temporal watershed analysis application and an urban growth forecasting application.

1. Introduction

Geospatial modeling provides mechanisms to evaluate and address socio-environmental problems, such as rapid urbanization, flooding, and water quality (Collins et al., 2022; Li and Gong, 2016; Miller et al., 2019). Traditional geospatial analysis and modeling methods rely heavily on desktop-based geographic information systems (GIS) software and expert domain knowledge. Sometimes these models require an interactive user interface ranging from web applications to tangible interfaces and augmented, virtual, or mixed reality (Gaydos et al., 2019; Koski et al., 2021b; Jones et al., 2021; Erazo Ramirez et al., 2022; Rigby et al., 2022). However, interactive user interfaces for geospatial models are difficult to develop in practice because of the cost, time, and technical resources needed for development.

The integral use of raster-based models is one of the challenges of developing interactive spatially explicit socio-environmental models. Rasters are well-suited for modeling socio-environmental phenomena because of their ability to model and manipulate continuous (e.g., elevation, satellite imagery) and discrete fields (e.g., land cover) using matrix-based mathematical operations. Rasters tend to have large file sizes, though, causing slow loading times, and limited interactive capabilities due to their volume (Farkas, 2020). However, advancements in remote sensing, such as increased data access (e.g., Sentinel-2 and Landsat) and new data providers (Planet Team, 2017), have addressed many of these issues. Additional advancements include the development of cloud-based computational platforms and application programming interfaces (APIs) (Gorelick et al., 2017; Neteler et al., 2019; Anon, 2022d), data formats such as the Meta Raster Format (MRF) (Anon, 2022c), format specializations like Cloud Optimized GeoTIFFs (COG) (Anon, 2022a), and specifications like the SpatioTemporal Asset Catalog (STAC) (STAC Contributors, 2021).

Furthermore, scalable data-on-demand cloud-based Earth observation platforms (e.g., openEO, Google Earth Engine, Microsoft Planetary Computer) are leveraging advancements in distributed computing and machine learning to enable a new era of data products. These data products include land use and land cover (LULC) monitoring (i.e., near real-time) (Brown et al., 2022), elevation change (White et al., 2022), flood extents (Tellman et al., 2021), and flood damage probability (Collins et al., 2022). Spatially explicit dynamic stochastic models (e.g., urban development, infectious disease) (Jones et al., 2021; Meentemeyer et al., 2013) and process-based physical models (e.g., surface water

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A4. ILWIS OPEN

CG9. A4

1. Descripción

Grass ILWIS es un Sistema de Información Geográfica (su acrónimo en inglés es: *Integrated Land and Water Information System*) y software de percepción remota para el manejo de información geográfica tanto ráster como vectorial. Las características principales de ILWIS son digitalización, edición, análisis y representación de geodatos así como la producción de mapas de calidad. ILWIS es famoso por su funcionalidad, facilidad de uso y bajo costo habiendo establecido una amplia comunidad de usuarios a lo largo de los años de su desarrollo.

Específicamente, las operaciones vectoriales que se pueden hacer con ILWIS incluyen, entre otras, conversión de datos analógicos a digital (digitalización), interpolación, análisis de patrones, cálculo de distancias, cálculo de distancias, la generación de Modelo Digital de Elevaciones (DEM), el cálculo de pendientes, la clasificación y cruces de mapas, la manipulación matemática, etc. Para las imágenes de satélite permite realizar corrección atmosférica, fusionado de imágenes, estadísticas multibanda, análisis multiespectral, etc.

ILWIS fue desarrollado y distribuido en un primer momento por ITC Enschede (International Institute for Geo-Information Science and Earth Observation) tras recibir una subvención para la elaboración de un SIG destinado al planeamiento y ordenación de los usos del territorio y las cuencas fluviales. En 1988 nació la primera versión de este programa y en 2007 pasa a convertirse en un software bajo licencia de documentación libre GNU, pasando a ser un software libre en su versión 3.4.

Las principales investigaciones en las que se ha usado ILWIS Open recientemente son AlAi et al., 2023; Danoedoro et al, 2023; Mavaringana et al., 2023; Nsegiyumva et al., 2018; Pacetti et al., 2023; Zamanpoore et al., 2023 y Wamala et al., 2023.

2. Características técnicas

Programa	ILWIS Open – Remote Sensing and GIS		
Versión	3.8.6	Año	2023
Tipología	Sistemas de Información Geográfica, Teledetección		
Capacidades del programa	ILWIS (Integrated Land and Water Information System) es un software GIS y de teledetección que integra imágenes, vectores y datos temáticos en un paquete único y poderoso. ILWIS ofrece una amplia gama de funciones que incluyen importación/exportación, digitalización, edición, análisis y visualización de datos, así como la producción de mapas de calidad. El software ILWIS es reconocido por su funcionalidad, facilidad de uso y bajo costo, y ha establecido una amplia comunidad de usuarios a lo largo de los años de su desarrollo.		
Sistema operativo			
	Windows (32 bits)		
Tipo de sistema (arquitectura)	32 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	ITC University of Twente/ 52°North – Spatial Information Research		
Web	https://52north.org/software/software-projects/ilwis/		

3. Ejemplos de trabajos científicos

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Article

Geospatial-Based Analytical Hierarchy Process (AHP) and Weighted Product Model (WPM) Techniques for Mapping and Assessing Flood Susceptibility in the Wadi Hanifah Drainage Basin, Riyadh Region, Saudi Arabia

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Abstract: This paper aimed to map areas prone to flooding in the Wadi Hanifah drainage basin located in the Riyadh region, and identify the most important factors that contribute to flooding through examining the influence of ten topographical, hydrological, and environmental variables affecting flood occurrence. Remote sensing data from Landsat-8, Shuttle Radar Topography Mission (SRTM), and other ancillary datasets were used to map relevant variables. Two weighted overlay techniques were used, including: analytical hierarchy process (AHP) and weighted product model (WPM). A correlation matrix and optimum index factor (OIF) were employed to identify the relative importance of each factor. The two derived flood susceptibility maps were assessed through validation by comparing the locations of historical flood events to susceptibility zones. The results confirmed the validity of the WPM map. The results also showed that nearly 50% of the study area was dominated by the "moderate" flood susceptibility zone, while about 33% of the total land area was classified as a "high" flood susceptibility zone. The "slope" factor was found to be the most effective variable for flood occurrence, followed by the "geology" variable, while the "distance to the drainage network" was the least important variable. The results of the OIF indicated that the best combination of factors dictating the variability of all flood susceptibility areas were "geology", "land use/cover (LULC)", and "soil type". The study findings are expected to be useful in understanding the effects of each factor on the spatial variation in flood occurrence and in improving flood control, and can be reapplied to other regions with similar climatic and environmental conditions worldwide.

Keywords: Riyadh region; flood susceptibility; AHP; WPM; GIS; Wadi Hanifah

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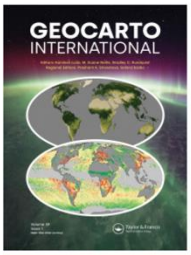
1. Introduction

Floods are described as a major type of natural disaster that occur worldwide, and they have become one of the most serious environmental issues [1]. According to Tehrany et al. [2] and Foody et al. [3], floods cause massive infrastructure damage and loss of life worldwide. Floods have also caused severe environmental disasters in most arid and semiarid regions [4]. Saudi Arabia, for example, is one of the countries that suffers from the negative effects of floods in some of its regions, such as Riyadh, Najran [5,6], and many others.

According to Elkhrachy [6], about 16% of the population of Najran city has been affected by floods. Flooding is also a serious problem for the Riyadh region and threatens the environment, human life, infrastructure, and economic development, especially in the northern and northeastern parts of the region [5]. An intense rainstorm (23.7 mm) on 19 November 2013 in Riyadh caused widespread flooding in many parts of the region.



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Vegetation structural composition mapping of a complex landscape using forest cover density transformation and random decision forest classifier: a comparison

Projo Danoedoro, Prima Widayani, Iswari Nur Hidayati, Sanjiwana Arjasakusuma, Diwyacitta Dirda Gupita & Huwaida Nur Salsabila

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Modelling future flood events under climate change scenarios in the Pungwe River Basin

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ABSTRACT

This study sought to project future changes in hydroclimatic variables and to establish how climate change affects flood inundation extent in the Pungwe River Basin. Climate ensembles of 10 Regional Climate Models from the CORDEX project were selected. The historical rainfall and temperature time series and the downscaled climate data were input into the HBV model to generate streamflow for the 2022–2099 period. Flood extents for 50-, 100-and 1,000-year return periods were predicted using the HEC-RAS hydraulic model. By 2070, annual rainfall at all nine studied meteorological stations is predicted to reduce by a maximum of 61%. Temperature is expected to increase up to 1.5% over the same period. By the 2070s, simulations from HBV revealed that the peak flows for the Pungwe River Basin will increase by up to 100% and decrease by approximately 57% as projected by the model ensemble. The analyses also show that by 2070 climate change may cause a minimum of 2,784.4 km^2 and a maximum of 8,235.6 km^2 of flood extension. These results are essential for decision-making on flood hazard mapping and early warning systems, prompting a pathway for sustainable development.

Key words: inundation extent, regional circulation models, return period, streamflow simulation, flood mapping

HIGHLIGHTS

- Satellite rainfall estimates, RCMs, hydrological, and hydraulic models for flood inundation extent mapping.
- By 2070, the future projections show increasing temperature and decreasing rainfall.
- Climate change will, however, increase peak flows and inundation extent by the 2070s.
- Significantly affected places in the Pungwe River Basin include cropland, built-up areas, roads, schools, hospitals, and business infrastructure.

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MDPI

Article

Landslide Susceptibility Assessment Using Spatial Multi-Criteria Evaluation Model in Rwanda

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Abstract: Landslides susceptibility assessment has to be conducted to identify prone areas and guide risk management. Landslides in Rwanda are very deadly disasters. The current research aimed to conduct landslide susceptibility assessment by applying Spatial Multi-Criteria Evaluation Model with eight layers of causal factors including: slope, distance to roads, lithology, precipitation, soil texture, soil depth, altitude and land cover. In total, 980 past landslide locations were mapped. The relationship between landslide factors and inventory map was calculated using the Spatial Multi-Criteria Evaluation. The results revealed that susceptibility is spatially distributed countrywide with 42.3% of the region classified from moderate to very high susceptibility, and this is inhabited by 49.3% of the total population. In addition, Provinces with high to very high susceptibility are West, North and South (40.4%, 22.8% and 21.5%, respectively). Subsequently, the Eastern Province becomes the peak under low susceptibility category (87.8%) with no very high susceptibility (0%). Based on these findings, the employed model produced accurate and reliable outcome in terms of susceptibility, since 49.5% of past landslides fell within the very high susceptibility category, which confirms the model's performance. The outcomes of this study will be useful for future initiatives related to landslide risk reduction and management.

Keywords: disaster; GIS; hazard; landslide; Rwanda; Spatial Multi-Criteria; susceptibility

1. Introduction

Landslides are confirmed severe forms of natural disasters [1] and most of them are caused by specific geological, geomorphological and climatological conditions as well as anthropogenic activities [2]. Landslides have been classified as the third most dangerous disaster [3], since they cause huge fatalities as well as enormous damages, especially in hilly topographic zones globally [4]. It is therefore necessary that strong and adequate measures are provided for preventing landslides and mass movements which will contribute to reducing associated impacts [5]. In many cases, this is not easily feasible due to various reasons, thus innovative and realistic approaches have to be adopted for enhancing landslides' risks management, and their susceptibility must be well mapped to enable rational decisions in line with landslide risk management [6,7].

In fact, landslide disasters have serious and diverse impacts. Globally, existing figures have confirmed their rise in damages and losses. The figures are much more serious in the last decade, with 32,322 fatalities recorded; monitoring, mapping and forecasting of these landslide hazards are less than adequate as required within different countries in the world [8]. Fast moving landslides such as

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Planning Nature Based Solutions against urban pluvial flooding in heritage cities: A spatial multi criteria approach for the city of Florence (Italy)

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Analytic Hierarchy Process (AHP)
Florence (Italy)

ABSTRACT

Study region: City of Florence, central Italy
Study focus: Aiming at defining a nature-based strategy to mitigate pluvial flood risk, a two-tiered methodology is proposed. Firstly, the areas prone to pluvial flood are identified by a spatial multi-criteria analysis that combines five criteria (imperviousness, slope, hydrologic soil groups, density of sewer system and social vulnerability) to build a Pluvial Flood Index (PFI). The PFI is validated by the comparison with historical pluvial flood events in the city and it is used for the identification of high priority areas for intervention. Then, this information is merged with the analysis of urban planning and NBS design constraints to identify the suitable areas for NBS installation.
New hydrological insights for the region: Results allow the definition of a NBS implementation strategy against pluvial flooding in the city of Florence, identifying for each pluvial flood hotspot the set of measures that can be implemented to solve the problem. The proposed approach represents a flexible assessment technique that can be reproduced in other urban context and provide useful support for NBS adoption in urban flood risk management for heritage cities.

1. Introduction

Urban pluvial floods occur when rainfall intensity locally exceeds infiltration and the conveyance capacity of the sewer system (Rosenzweig et al., 2018, Tanaka et al., 2020; Bulti and Abebe, 2020). They represent a major challenge worldwide (Villordon and Gourbesville, 2014; Schmitt ans Scheid, 2020) both because of their small temporal scale making their prediction complex (Li and Willems, 2020), and due to the extensive damage to property and people they can cause (Yin et al., 2016). Moreover, climate change, ongoing urbanization, reductions in urban green spaces and deteriorating urban water management infrastructures are further increasing pluvial flood risk (Kaykhosravi et al., 2019; O'Donnell and Thorne, 2020; Zölch et al., 2017; Pachauri et al., 2014) and questioning the effectiveness of traditional management approaches (Westra et al., 2014). Indeed, grey infrastructures, or hard engineering solutions - designed only to collect rainwater and convey it away from the city context through sewer systems (Li et al., 2020) - often show their inadequacy to deal with very intense and locally concentrated rainfall events. Moreover, such solutions will not

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Research Paper

Habitat Classification of Maharlu Wetland Using MedWet Classification System

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Playa
Saline Lake

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Abstract

Identifying the different habitats in wetlands is essential for their protection. This research was carried out with the aim of classifying habitat areas of Maharlu wetland in Fars province using MedWet, Mediterranean Wetland Habitat Classification System. Information on dominant vegetation cover, soil, and hydrology of the wetland was prepared using field surveys. The data on the water regime were obtained with quarterly satellite images from 2016-2019 in remote sensing media using ArcGIS. Sampling was performed for wetland plants and lake bed outcrops from 39 stations in May 2020. Plants were identified and classified on the basis of being an annual or perennial presence and submerged or floating. By stacking this information in ILWIS, different habitat zones were separated. Each was then specified using habitat international standard codes, and habitat maps were prepared. In total, 42 habitats were identified in the Maharlu wetland. The most prevalent habitats were palustrine–emergent–persistent–seasonally flooded–Mixosaline– (P-EPSX-) (14,797,300 m^2), palustrine–emergent–persistent–temporarily flooded– Mixosaline (P-EPSX-) (296,600 m^2), lacustrine–littoral–emergent–persistent–seasonally flooded–mixosaline– (LLEPSX) (2,079,900 m^2), and lacustrine–littoral–emergent–persistent–Semipermanently flooded–mixosaline– (LLEPLX-) (493,000 m^2). The results of this research in recognizing habitats are useful for the protection of ecosystem sections, especially plant communities.

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Assessment of irrigation water distribution using remotely sensed indicators: A case study of Doho Rice Irrigation Scheme, Uganda

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Keywords:
Actual evapotranspiration
Irrigation performance assessment
Surface energy balance system
Equity
Adequacy

ABSTRACT

The rising competition for scarce land and water resources and the need to satisfy the global food demand from an ever-growing population necessitates novel methods to monitor irrigation scheme performance for improved water use efficiency. The traditional methods employed in sub-Saharan Africa to assess irrigation performance are point-based, expensive, and time-consuming, making monitoring and evaluation of these capital-intensive projects difficult. This study aimed at employing satellite data with high spatial and temporal resolution in assessing the performance of Doho Rice Irrigation Scheme through estimations of actual evapotranspiration. Actual evapotranspiration (ET_a) was modelled from Landsat 7 imagery using the surface energy balance system algorithm on five clear days between January and April 2020. Using equity and adequacy metrics, the derived ET_a was used to assess the irrigation performance of the scheme. Results showed that the equity indicator was generally fair, with the coefficient of variation between 0.11 and 0.08, close to the 0.10 threshold implying irrigation water is fairly distributed within the scheme. The average adequacy was 0.87, above the 0.65 threshold, indicating adequate water supply throughout the scheme. The study's findings can be used in future research and benchmarking with other irrigation schemes to address the country's water resource management challenges.

1. Introduction

The projected global population growth and the expected increase in food demand coupled with the changing climate patterns are likely to constrain water use for agricultural production [1–3]. In addition, irrigated agriculture has shaped itself at the centre of meeting the future food demand amidst climate change and sustainability challenges [4]. As much as 70% of the world's freshwater is abstracted for irrigation purposes, a significant portion of it is lost due to inefficient irrigation systems [5]. Therefore, performance assessment in irrigated agriculture is a requirement for sustainable food production. The performance level of surface and pressurized irrigation systems and their sustainability will determine if humanity will be able to meet the food demand by 2050 amidst climate change challenges [6].

In sub-Saharan Africa, assessing the performance of irrigation systems has been carried out by various scholars [1, 7-11]. However, one common challenge reported by these scholars is insufficient data in conducting the studies. Most irrigation schemes have poor record-keeping systems and also lack water accounting infrastructure, thus hindering primary data collection for research. This is usually attributed to the high cost associated with monitoring, lack of measurement structures and poor scheme management. This has affected the modernization plans of most schemes as baseline data is insufficient. Coupling ground-based observations and remotely sensed data would help the surface irrigation scheme in sub-Saharan Africa curb this problem.

Remote sensing is a powerful tool that can be used to understand agricultural performance at high spatial and temporal resolutions [12–14]. The application of remote sensing in estimating agricultural performance indicators is becoming more prolific as it provides more information, in both time and space than can be provided by traditional methods, such as water balance or ground measurements [15, 16]. Remote sensing can provide insight into various aspects of agricultural production, including the estimation of ET_a and biomass production

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B. MODELOS HIDROLÓGICOS, HIDRÁULICOS E HIDROGEOMORFOLÓGICOS (EROSIÓN)

B.1. HEC-HMS

CG9. B1

1. Descripción

HEC-HMS es un software de modelado hidrológico (Hydrologic Modeling System) diseñado para simular los procesos de precipitación y escorrentía de las cuencas de drenaje dendríticas. Aunque también está diseñado para ser aplicable en una amplia gama de áreas geográficas para resolver un mayor número de problemas.

Algunas de las operaciones que incluye este programa es el suministro de agua de la cuenca y las inundaciones además de la escorrentía de cuencas urbanas o naturales. HEC-HMS proporciona hidrogramas que pueden ser usados directamente o junto con otros programas para estudios de disponibilidad de agua, drenaje urbano, pronósticos sobre el flujo de agua, reducción de daños por inundación, etc.

HEC-HMS es un producto del Centro de Ingeniería Hidrológica (HEC) del Cuerpo de Ingenieros del Ejército de los EEUU. El programa se desarrolló a partir de 1992 como reemplazo de HEC-1, que fue el programa base para la simulación hidrológica. HEC-HMS ofrece las mismas capacidades que su antecesor, pero se ha modernizado con avances en el análisis numérico, la simulación continua y una mejora de su interfaz gráfica, entre otras.

HEC-HMS está siendo usado de manera generalizada en múltiples propósitos, incluyendo la investigación de los recursos hídricos.

Las principales investigaciones en las que se ha usado HEC-HMS recientemente son Acheampong et al., 2023; Adams et al., 2023; Chakraborty y Biswas, 2021; El Yousfi et al., 2023; Guido et al., 2023; Hassan et atl., 2023; Namwade et al., 2023 y Unucka y Kamínková, 2023.

2. Características técnicas

Programa	HEC-HMS		
Versión	4.10	Año	2022
Tipología	Modelación hidrológica		
Capacidades del programa	Hydrological Modeling System (HMS) es un software diseñado para simular los procesos hidrológicos completos de los sistemas de cuencas dendríticas. Incluye múltiples procedimientos tradicionales como la infiltración de eventos o los hidrogramas unitarios. HEC-HMS también puede realizar simulación continúa incluyendo la evapotranspiración, el deshielo y la humedad del suelo. También se puede calcular la escorrentía mediante modelos, la predicción de flujo, la erosión y el transporte de sedimentos e, incluso, la calidad del agua.		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC)		
Web	https://www.hec.usace.army.mil/software/hec-hms/		

3. Ejemplos de trabajos científicos

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Impacts of retention basins on downstream flood peak attenuation in the Odaw river basin, Ghana

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Keywords:
Flood arrival time
Flood attenuation
HEC-RAS
Odaw river basin (ORB)
Retention basin
Return period

ABSTRACT

Study region: Odaw River Basin (ORB) in Ghana
Study focus: We simulated and examined the impacts of retention basin as a hydraulic structure in attenuating the flood peaks downstream of the ORB with a coupled HEC-HMS and HEC-RAS models for different flood scenarios. Calibrated and validated HEC-HMS models were used to forecast floods in terms of peak flows and results forced into the 2D Unsteady flow HEC-RAS model to simulate flood inundation areas.
New hydrological insight for the region: The calibrated and validated HEC-HMS model indicated good performance (NSE > 0.65) in simulating the runoff characteristics of the basin. Forecasted peak flows with the calibrated model for return periods of 30-to-1-year were 131.1 m^3/s, 121.6 m^3/s, 106.4 m^3/s, 88.8 m^3/s and 59.3 m^3/s respectively for the "without" a retention basin scenario within the ORB. In the "with" retention basin scenario, attenuated peak flows were observed downstream the ORB by 8.1 % (120.5 m^3/s), 8.4 % (111.4 m^3/s), 9.1 % (96.7 m^3/s), 13.6 % (76.7 m^3/s) and 13.2 % (51.5 m^3/s) respectively for the different return periods. Flood volumes reaching downstream of the basin reduced by 2.3 %, 2.5 %, 2.7 %, 3.0% and 3.8 % respectively due to the presence of the retention basin. The retention basin increased the basin lag time by an average of 4 h across all different flood scenarios. The introduction of retention basins will serve a pivotal role in flood management and planning in the ORB.

1. Introduction

Floods have become a rampant natural disaster in a number of countries and hence a global concern (Singh et al., 2018). Since the 2000 s, the number of flood cases in the world have nearly doubled when compared to the 1990s (Guha-Sapir et al., 2004). Floods poses serious threat with huge socio-economic burden and health implications on victims. (CRED, 2018). Extreme events in Africa, Europe, and Asia demonstrate the importance of climate change in causing increased flood incidences. Floods are linked not only to climate change but also to urbanization dynamics (Hassan et al., 2022). In Sub-Saharan Africa, floods are deemed as the most commonest natural disaster with the propensity of disrupting socio-economic activities, altering ecosystem services and functions and ultimately impacting on the quality of lives. (Pusch et al., 2016; CRED, 2018).

On the global scale, aside disease outbreaks and accidents, flooding is the third most common environmental disaster adversely claiming 20 million lives annually (Asumadu-Sarkodie et al., 2015). In Ghana, hydro-meteorological risks have been identified as the

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Advancing stream classification and hydrologic modeling of ungaged basins for environmental flow management in coastal southern California

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Abstract. Environmental streamflow management can improve the ecological health of streams by returning modified flows to more natural conditions. The Ecological Limits of Hydrologic Alteration (ELOHA) framework for developing regional environmental flow criteria has been implemented to reverse hydromodification across the heterogenous region of coastal southern California (So. CA) by focusing on two elements of the flow regime: streamflow permanence and flashiness. Within ELOHA, classification groups streams by hydrologic and geomorphic similarity to stratify flow–ecology relationships. Analogous grouping techniques are used by hydrologic modelers to facilitate streamflow prediction in ungaged basins (PUB) through regionalization. Most watersheds, including those needed for stream classification and environmental flow development, are ungaged. Furthermore, So. CA is a highly heterogeneous region spanning gradients of urbanization and flow permanence, which presents a challenge for regionalizing ungaged basins. In this study, we develop a novel classification technique for PUB modeling that uses an inductive approach to group perennial, intermittent, and ephemeral regional streams by modeled hydrologic similarity followed by deductively determining class membership with hydrologic model errors and watershed metrics. As a new type of classification, this hydrologic-model-based classification (HMC) prioritizes modeling accuracy, which in turn provides a means to improve model predictions in ungaged basins while complementing traditional classifications and improving environmental flow management. HMC is developed by calibrating a regional catalog of process-based rainfall–runoff models, quantifying the hydrologic reciprocity of calibrated parameters that would be unknown in ungaged basins and grouping sites according to hydrologic and physical similarity. HMC was applied to 25 USGS streamflow gages in the "South Coast" region of California and was compared to other hybrid PUB approaches combining inductive and deductive classification. Using an average cluster error metric, results show that HMC provided the most hydrologically similar groups according to calibrated parameter reciprocity. Hydrologic-model-based classification is relatively complex and time-consuming to implement, but it shows potential for simplifying ungaged basin management. This study demonstrates the benefits of thorough stream classification using multiple approaches and suggests that hydrologic-model-based classification has advantages for PUB and building the hydrologic foundation for environmental flow management.

1 Introduction

The natural variability of streamflow regimes, including flow magnitude, duration, frequency, timing, and rate of change (Poff et al., 1997), is crucial for maintaining the ecological integrity of streams (Bunn and Arthington, 2002). Maintenance of aquatic and riparian ecosystem functions is a major priority for water managers; however, streamflow regimes have been altered globally as population growth and development lead to urbanization, dams, flow extraction, and other land use changes (Naiman et al., 1995; Richter et al., 1997).

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ORIGINAL PAPER

Simulation of flow at an ungauged river site based on HEC-HMS model for a mountainous river basin

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Abstract
Considering the severity of a catastrophic flood in the Teesta river in India earlier, it is indispensable to assess the runoff at the basin's ungauged outlet, Mekhliganj. Almost every other year, the downstream of the river is in spate during the monsoon months. Among the three gauging stations in the basin, Teesta Bazaar, Domohani, and Mekhliganj, streamflow data is unavailable at the latter one. In this context, this study focuses on estimating the runoff of the Teesta river basin at its outlet, Mekhliganj, using Hydrologic Engineering Center-Hydrological Modeling System (HEC-HMS) software, verifying the output from the model through the measured streamflow data at the other two upstream gauging locations, Teesta Bazaar and Domohani. The runoff has been estimated for daily precipitation from May to October, applying Soil Conservation Service (SCS), curve number (CN), and SCS unit hydrograph method. Subsequently, the model has been calibrated for 2001 and 2006 to optimize both the Muskingum routing parameters. The model has been validated for some specific years like 2004, 2012, 2013, and 2016, which experienced extreme deluge. The results for both the upstream gauging stations bear a good correlation between the computed and observed data, evaluated through the statistical indicators such as percentage error in peak flow (PEPF), percentage error in volume (PEV), Nash-Sutcliffe (NSE), and R^2, consequently justifying the simulated result at the outlet. This study is necessary for this vast watershed area with limited gauging stations and an ungauged outlet to understand the basin response and its derived consequence.

Keywords Teesta river · India · HEC-HMS · SCS-CN · Muskingum · Rainfall-runoff · NSE

Introduction

Over the decades, natural hazards have been occurring in an unanticipated manner with frightening consequences. It is well accepted that floods are a sudden phenomenon and have tremendous potential to ravage livestock, property, and human society, bringing life to a standstill. Flooding results from extreme hydrometeorological events and occurs with unexpected magnitude and varying frequencies. Adequate estimation of runoff volume and flood peaks plays a pivotal role in issuing an early warning and framing policies to curb human loss and property. Proper evaluation of surface runoff of a catchment area involves profound knowledge about the influencing factors and assists in sustainable water resource planning and management strategies. Rainfall-runoff modeling for a catchment area is a classical approach for understanding the hydrological response of the area. Rainfall-runoff models are most commonly involved in solving various assignments, like modeling flood events, tracking water levels for various water conditions, or flood forecasting (Jia et al. 2009). The amount of surface runoff is determined by soil characteristics, land use features, hillslope, vegetation, and storm properties, such as the duration, amount, and intensity of rainfall (Sitterson et al. 2017). An amalgamation of two mechanisms, saturation excess and infiltration excess, results in the generation of runoff (Yang et al. 2015). The hydrological models are built incorporating the constitutive equations involving many interconnected input variables like precipitation, infiltration losses, and information regarding basin characteristics to simulate the runoff volume and flood peak.

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GIS preprocessing for rainfall-runoff modeling using HEC-HMS in Nekkor watershed (Al-Hoceima, Northern Morocco)

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Abstract. All Discharge data are among the most critical factors that must be considered when evaluating the management of water resources in a watershed. Simulation of rainfall-runoff is therefore an important element in assessing the impacts of serious flooding. In the present study, rainfall-runoff in the Nekkor watershed in Al Hoceima province was simulated using GIS, remote sensing and the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model. The applicability, capacity and suitability of this model for rainfall runoff in the watershed were examined. The watershed parameters were generated using (HEC-GeoHMS) and ArcGIS. The model was calibrated using a daily data set that occurred in the watershed between 2003 and 2007, the validation period was from 2009 to 2012. Model performance was evaluated using a variety of different statistical indices to study the response and impact of rainfall-runoff. Model parameters were changed and calibration was performed using the Soil Conservation Service Curve Number loss method. Consistent and satisfactory performance in terms of peak discharge, total flood volume, timing of peak discharge and overall hydrograph adjustment effect was found. The determination coefficient (R^2) for the validation period reached 0.73 versus 0.71 for the calibration period. The root mean square error (RMSE) is within the acceptable range. The relative bias (RE) demonstrates an overestimation in the calibration period and an underestimation in the validation period in the peak flows. These results will help decision makers to better manage water resources in this watershed and mitigate flood risks.

1 Introduction

Rainfall and runoff are major constituents of the hydrologic cycle. Hydrological models are now widely used to simulate the spatiotemporal variability of water flows. A flood is characterized by abnormally elevated water levels that extend beyond the channel or the channel bank [1]. Therefore, a few catchments have enough continuous hydrologic measurements for accurate water resource evaluations [2,3]. It is important to know the volume of runoff in a given watershed for the efficient planning and management of durable water resource projects. Present and future water associated challenges are place and time-specific, such can differ

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An integrated modeling approach to evaluate the impacts of nature-based solutions of flood mitigation across a small watershed in the southeast United States

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Abstract. Floods are among the most destructive natural hazards in the world, posing numerous risks to societies and economies globally. Accurately understanding and modeling floods driven by extreme rainfall events has long been a challenging task in the domains of hydrologic science and engineering. Unusual catchment responses to flooding cause great difficulty in predicting the variability and magnitude of floods, as well as proposing solutions to manage large volumes of overland flow. The usage of nature-based solutions (NBSs) has proved to be effective in the mitigation of flood peak rate and volume in urban or coastal areas, yet it is still not widely implemented due to limited knowledge and testing compared to traditional engineering solutions. This research examined an integrated hydrological and hydraulic modeling system to understand the response of an at-risk watershed system to flooding and evaluate the efficacy of NBS measures. Using the Hydrologic Engineering Center Hydrologic Modeling System and River Analysis System (HEC-HMS and HEC-RAS) software, an integrated hydrologic–hydraulic model was developed for Hurricane Matthew- (2016) and Florence-driven (2018) floods across the Little Pee Dee–Lumber River watershed, North and South Carolina (the Carolinas), US. The focus was on Nichols, a small town that has disproportionately been impacted by flooding during these two hurricane events.

The present article proposes a methodology for selecting, modeling, and evaluating the performance of NBS measures within a catchment, which can be extended to other case studies. Different NBS measures, including flood storage ponds, riparian reforestation, and afforestation in croplands, were designed, modeled, and evaluated. Hurricane Matthew's flooding event was used for evaluating the NBS scenarios given its high simulation accuracy in flood inundation compared to the less accurate results obtained for Hurricane Florence. The scenario comparison evidenced that large-scale natural interventions, such as afforestation in croplands, can reduce the inundated area in Nichols by 8 % to 18 %. On the contrary, the smaller-scale interventions such as riparian reforestation and flood storage ponds showed a negligible effect of only 1 % on flood mitigation.

1 Introduction

Floods are among the most destructive natural hazards in the world, posing numerous risks to societies and economies globally (European Parliament, 2017; IPCC, 2022). The socioeconomic impacts of flooding are numerous, negatively affecting human life, health, livelihoods, and critical infrastructure, among others (Phillips et al., 2018; IPCC, 2022).

In the United States, flooding and severe storms are among the most recurrent weather and climate disasters, which have caused USD 492 billion in economic damages in the past 30 years (Smith, 2020). The US Gulf and East Coast are vulnerable to destructive tropical storms and hurricanes, which can generate storm surges and riverine flooding along the exposed communities (NOAA, 2020). Since the 1970s inland flooding has been responsible for more than half of all deaths associated with tropical cyclones in the United States

water

MDPI

Article

Investigating the Effects of Climate and Land Use Changes on Rawal Dam Reservoir Operations and Hydrological Behavior

Sharjeel Hassan [1,2], Muhammad Umer Masood [1], Saif Haider [1,3], Muhammad Naveed Anjum [2,*], Fiaz Hussain [2], Yongjian Ding [4,*], Donghui Shangguan [4], Muhammad Rashid [1] and Muhammad Umer Nadeem [5]

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Abstract: In order to assess the effects of climate change and land use change on Rawal Dam, a major supply of water for Rawalpindi and Islamabad, this study uses hydrological modeling at the watershed scale. The HEC-HMS model was used to simulate the hydrological response in the Rawal Dam catchment to historical precipitation. The calibrated model was then used to determine how changes in land use and climate had an impact on reservoir inflows. The model divided the Rawal Dam watershed into six sub-basins, each with unique features, and covered the entire reservoir's catchment area using data from three climatic stations (Murree, Islamabad Zero Point and Rawal Dam). For the time spans of 2003–2005 and 2006–2007, the model was calibrated and verified, respectively. An excellent fit between the observed and predicted flows was provided by the model. The GCM (MPI-ESM1-2-HR) produced estimates of temperature and precipitation under two Shared Socioeconomic Pathways (SSP2 and SSP5) after statistical downscaling with the CMhyd model. To evaluate potential effects of climate change and land use change on Rawal Dam, these projections, along with future circumstances for land use and land cover, were fed to the calibrated model. The analysis was carried out on a seasonal basis over the baseline period (1990–2015) and over future time horizon (2016–2100), which covers the present century. The findings point to a rise in precipitation for both SSPs, which is anticipated to result in an increase in inflows throughout the year. SSP2 projected a 15% increase in precipitation across the Rawal Dam catchment region until the end of the twenty-first century, while SSP5 forecasted a 17% increase. It was determined that higher flows are to be anticipated in the future. The calibrated model can also be utilized successfully for future hydrological impact assessments on the reservoir, it was discovered.

Keywords: land use classification; Rawal dam; climate change; land use/land cover change; statistical downscaling; GCMs

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1. Introduction

Due to the scarcity of water resources, it is necessary to guarantee everyone's survival and socioeconomic growth. The increasing population and development efforts are placing stress on the world's water resources [1]. Over the past century, water extraction has increased six fold globally, twice as quickly as population development. One-fifth of the world's population struggles with a physical water shortage, which may soon impact 500 million people [2]. According to estimates, 65% of the world's rivers and aquatic environments face imminent peril [3]. There has been devastation to the ecology and

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Rainfall-Runoff Modelling Using HEC-HMS Model, Remote Sensing and GIS in Middle Gujarat, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Hydrological modeling is a widely used approach for estimating the hydrological response of a basin to precipitation. Floods are among the most catastrophic natural disasters in small urban watersheds, inflicting loss of life, massive property destruction, and a severe danger to the economy. As a result, appropriate modeling can be a useful tool in preventing and mitigating such flood hazards. Despite this, flash flood prediction remains one of the challenges of hydrological modeling in ungauged basins due to a lack of runoff observations. This study aims to calibrate and validate the rainfall-runoff transformation model for Hathmati river sub watershed in the Sabarmati River basin using HEC-HMS (Hydrologic Engineering Centre Hydrology Modeling System). For the loss rate, SCS Curve Number method was selected while Clark Unit Hydrograph and SCS unit

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Application for the parametrization and automatic running of the HEC-HMS rainfall-runoff model

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Keywords: hydrologic modelling – HEC-HMS – HEC-RAS – GIS – automatic launching – parametrization of models

ABSTRACT

This article presents an application developed in the Czech Hydrometeorological Institute (CHMI) to support hydrologic modelling using the HEC-HMS model as the primary used rainfall-runoff model. The application enables group editing of selected parameters of the model schematization, automatic running of simulations, display of selected simulation results, and communication of the HEC-HMS model with GIS and other selected models, e.g., HEC-RAS or MIKE 11. The application is designed to use only freeware and open source libraries and is capable of operating under both Windows OS and UNIX/Linux OS. This article briefly describes the current state of the application development and its functionality, even for readers without major IT background. Further development is outlined in the last part of the article. Further development of the application is aimed at higher support for hydraulic modelling at the level of communication between the HEC-HMS and HEC-RAS models, as well as at the level of automatic parameterization and launching of the HEC-RAS model and its communication with other tools, e.g. hydraulic model MIKE 11 or GIS post-processing of the results.

INTRODUCTION

The HEC-HMS (Hydrologic Engineering Center Hydrologic Modeling System) software for rainfall-runoff modelling is one of the most widely used worldwide and its popularity is growing. One of the main reasons is the fact that it is distributed as freeware, including rich documentation [7]. Other reasons include the ever-expanding palette of methods for hydrological and hydraulic transformation in semi- and fully distributed solutions (e.g., SCS-CN, Green-Ampt, SAC-SMA, kinematic wave approximation, Muskingum-Cunge, linear reservoir) and also the fact that it is validated and listed as a FEMA/NFIP industry standard [8]. Last but not least, it is also the possibility to communicate with the HEC-RAS hydraulic model and the HEC-ResSim model for operational simulation and optimization of water management systems, while the integration possibilities are significantly increased by the HEC-WAT (Watershed Analysis Tool) and HEC-RTS (Real Time Simulation) platforms. Another significant advantage is the possibility of operation on multiple operating systems, namely Windows, UNIX/Linux, and macOS. This software is used in CHMI for assessment activities, hydrological analyses and, at the Ostrava branch, together with the HYDROG rainfall-runoff model, for operational hydrological forecasting within the framework of the Flood Warning and Forecasting Service (FWFS) of the Czech Republic. Other aspects are also important for operational hydrological forecasting; the most fundamental ones include the possibility of automatic or semi-automatic adjustment of selected parameters, calibration and optimization, as well as automatic launching. The HEC HMS software has an advanced API (Application Programming Interface) in the new versions based on the Java, Python, and Jython languages. For this reason, an application that makes these automatic and semi-automatic functions of HEC-HMS available to users and expands them was gradually created at CHMI Ostrava. The basic motivation was to shorten the processing time of the input and output data of rainfall runoff modelling, as well as the full or partial automation of some steps within the rainfall-runoff modelling itself, for example updating the parameters of the runoff loss methods according to the indicator of previous rainfall, or conversion of schematics between the SCS-CN and Green-Ampt methods.

Operation of the HEC-HMS model at CHMI Ostrava

The HEC-HMS rainfall-runoff model has been gradually introduced and tested at the CHMI Ostrava branch since 2013. It has been routinely operated to predict flows on selected flood warning profiles on watercourses within the branch's territorial jurisdiction since 2017, and serves as a support system that is used during the decision-making process when issuing warning information on flood phenomena within the Integrated Warning Service System [5]. Data for rainfall-runoff modelling are exported from the CLIDATA database system, specifically from the SOMDATA module [3] in the required format and structure, and subsequently imported into the HEC-DSSVue database system [6], which uses the HEC-HMS model along with other USACE/HEC tools as well. After the actual calculation in the HEC-HMS model, the results are then exported from the HEC-DSSVue database, and then again, in the required format, imported back into the CLIDATA database for further use in operational practice.

For the actual prediction of flows in the HEC-HMS model, the Forecast Alternatives module (hereafter Forecast) is available in which the date and time of simulation and prediction are set; subsequently, the module is connected to a specific basin model (Basin), the meteorological model is specified, and the configurations are set that can be used to adjust (calibrate) model parameters (set methods of hydrological and hydraulic transformation of rainfall and base runoff) [7]. The advantages of using it in everyday operation are a clear user environment, the speed of the calculation itself, and the possibility of calibrating individual parameters. Due to the steps described above, automation

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B.2. HEC-RAS

CG9. B2

1. Descripción

HEC-RAS es un programa para la modelización del flujo de agua a través de ríos naturales y canales artificiales. Este software es gratuito, por lo tanto, su uso se ha generalizado y se encuentra en un proceso constante de actualización al introducir continuas mejoras.

HEC-RAS es un producto del Centro de Ingeniería Hidrológica (HEC) del Cuerpo de Ingenieros del Ejército de los EEUU (al igual que HEC-HMS). Este centro ha desarrollado el *River Analysis System* (RAS) para ayudar a los ingenieros hidráulicos en el análisis del flujo del canal y la determinación de la llanura aluvial. Incluye numerosas capacidades de entradas de datos, componentes de análisis hidráulicos, almacenamiento de datos y capacidades de gestión y una gran variedad de funciones gráficas e informes.

Hasta el lanzamiento de su última versión en 2016 (5.0.) el programa era unidimensional, lo que significa que no había un modelado directo del efecto hidráulico de los cambios de forma de la sección transversal, las curvas y otros aspectos bi-tridimensionales del flujo. Con la versión 5.0 se introdujo el modelo bidimensional de flujo, así como las capacidades de modelado de transferencia de sedimentos. Por lo tanto, HEC-RAS ha evolucionado en muchos aspectos desde su lanzamiento público en 1995, como en la interoperabilidad con otros softwares como ArcGIS, AUTOCAD o MicroStation.

HEC-RAS se emplea de manera generalizada en investigación de los recursos hídricos. Las principales investigaciones en las que se ha usado recientemente son Bennet at al., 2023; Haces-Garcia et al., 2023; Lee y Ahn, 2023; Prajapati set al., 2023; Sceiber et al., 2023; Siregar, 2018 y Uca et al., 2023.

2. Características técnicas

Programa	HEC-RAS		
Versión	6.4	Año	2023
Tipología	Modelación hidrológica		
Capacidades del programa	River Analysis System (RAS) es un software que permite al usuario realizar cálculos de flujo estacionario unidimensional, flujo no estacionario unidimensional y bidimensional, cálculos de transporte de sedimentos/lecho móvil y modelado de temperatura/calidad del agua.		
Sistema operativo	Linux (64 bits): versión anterior (6.1)		
	Windows (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC)		
Web	https://www.hec.usace.army.mil/software/hec-ras/		

3. Ejemplos de trabajos científicos

Natural Hazards (2023) 118:277–305
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ORIGINAL PAPER

Modelling compound flooding: a case study from Jakarta, Indonesia

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Abstract
The paper investigates compound flooding from waves, sea surge and river flow in northern Jakarta, Indonesia, which is a global hotspot of flooding, by combining process-based coastal and river models. The coastal hydrodynamic modelling of Jakarta Bay in Indonesia shows that coastal storms can lead to a substantial increase in sea water level due to wind and wave setup in the nearshore areas, including Muara Angke river inlet. The compound flood hazard from a range of flood scenarios was simulated and analysed. The results reveal that low-lying areas around the river inlet are prone to flooding even during regular, low-intensity storm events, while rarer storms caused extensive floods. Floods were not caused by direct overwashing of sea defences but by overspill of the banks of the river inlet due to high sea water level caused by wind set up, wave setup, and sea surge obstructing the drainage of the river and elevating its water level during storms. We also found that the sea level rise combined with rapid land subsidence will inundate the existing coastal flood defences during storms in future. The majority of the city will be below mean sea level by 2100. The overflow of existing coastal defences will lead to extensive flooding in northern, western, and eastern Jakarta unless the defences are upgraded to keep up with future sea level rise.

Keywords Jakarta · Indonesia · Compound flooding · Process-based modelling · Extreme storms · Sea level rise

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Deep Learning Hydrodynamic Forecasting for Flooded Region Assessment in Near-Real-Time (DL Hydro-FRAN)

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April 2023

1 Abstract

Hydrodynamic flood modeling improves hydrologic and hydraulic prediction of storm events. However, the computationally intensive numerical solutions required for high-resolution hydrodynamics have historically prevented their implementation in near-real-time flood forecasting. This study examines whether several Deep Neural Network (DNN) architectures are suitable for optimizing hydrodynamic flood models. Several pluvial flooding events were simulated in a low-relief high-resolution urban environment using a 2D HEC-RAS hydro-

sustainability

MDPI

Article

Analysis of Bed Sorting Methods for One Dimensional Sediment Transport Model

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Abstract: Proper estimation of sediment movement is very critical for the management of alluvial rivers. Computing the sediment transport with single particle size is possible. However, particles on the river bed and in transport have a size distribution. It is very important to estimate bed material size change, such as bed armoring, in case of scour. In this study, the applicability of the bed sorting method, which is available with HEC-RAS, was analyzed. Bed sorting methods divide the bed into two or three layers. Numerical simulations were conducted in the Geum River, Korea. The performance of the simulation with respect to bed sorting methods was evaluated by considering the temporal change of bed material size during the scour and armoring process. Three layer methods are not applicable for a natural river and had oscillatory temporal bed material size variation. The two layer method has stable temporal bed material size changes and predicts the armoring of the bed properly even with limited field data. Consequently, the active layer method is reliable for natural rivers to simulate the bed material size change while applications of three layer methods require sufficient investigation.

Keywords: active layer; bed sorting method; Copeland method; deposition; HEC-RAS; scour; sediment transport; Thomas method

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1. Introduction

The fluvial process is a dominant factor in the shape of a river. The change of topography affects the hydraulics of the river. Furthermore, the safety and the functional performance of hydraulic structures are affected by the change of topography. Sedimentation causes floods by reducing reservoir capacity and reducing flow area [1]. Flood level rise and water storage capacity reductions in reservoirs due to sedimentation should be solved. Scour dominant cases cause bridge failures [2,3]. Many cases of bridges failure due to excessive scour induced by flood have been reported [4,5]. Scour caused 60% of the destruction of more than 1000 piers in the United States over a period of 30 years [2,6]. Numerous European bridges were damaged due to scour as well [7]. Similarly, bridge failures were observed in South America and Asia [8–11]. Therefore, it is necessary to estimate the amount of sediment erosion and deposition properly to respond to the sediment problems.

Numerous studies were conducted to understand the behavior of sediment particles. Ahn and Yang (2015) suggested a method for determining the recovery factor for the simulation of non-equilibrium sedimentation to reflect the spatial and temporal delay of sediment particle movement. The applicability was verified by comparing the simulation results with previous studies [12]. The flow instability during a flood affects the structures and particle behaviors. Previous studies demonstrated that the analysis of sediment particle behavior is important for an unsteady state by showing that the sediment transport can vary depending on flow conditions [13].

water

MDPI

Article

Modelling Transport and Fate of Copper and Nickel across the South Saskatchewan River Using WASP—TOXI

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Abstract: The South Saskatchewan River (SSR) is one of the most important river systems in Saskatchewan and, arguably, in Canada. Most of the Saskatchewan residents, industries, and power-plants depend on the SSR for their water requirements. An established 1D modelling approach was chosen and coupled with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). The WASP (Water Quality Analysis Simulation Program) stream transport module, TOXI, is coupled with flow routing for free-flow streams, ponded segments, and backwater reaches and is capable of calculating the flow of water, sediment, and dissolved constituents across branched and ponded segments. Copper and nickel were chosen as two metals with predominantly anthropogenic (agriculture, mining, and municipal and industrial waste management) and geogenic (natural weathering and erosion) sources, respectively. Analysis was carried out at ten different sites along the South Saskatchewan River, both upstream and downstream of the City of Saskatoon, in the years 2020 and 2021. Model performance was evaluated by comparing model predictions with concentrations of copper and nickel measured in a previously published study. The model performed well in estimating the concentrations of copper and nickel in water samples and worked reasonably well for sediment samples. The model underestimated the concentration values at certain segments in both water and sediment samples. In order to calibrate the model more accurately, extra diffusive contaminant loads were added. While several default parameter values had to be used due to the unavailability of primary historical data, our study demonstrates the predictive power of combining WASP—TOXI and HEC-RAS models for the prediction of contaminant loading. Future studies, including those on the impacts of global climate change on water quality on the Canadian prairies, will benefit from this proof-of-concept study.

Keywords: copper; nickel; trace metals; pesticides; WASP; HEC-RAS

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1. Introduction

Contamination of the environment with various trace metals has been of significant concern for many decades due to their potential to cause deleterious impacts on exposed wildlife and humans. Trace metals have several unique chemical properties that dictate their environmental fate and bioavailability. Trace metals such as copper, nickel, zinc, and lead are inclined to interact with other elements and organic molecules present in the environment. Assessments of environmental fate and risks of trace metal exposure to wildlife and humans historically only accounted for these interactions superficially and are most commonly based on total metal concentrations. Thus, there is a need to develop methods and strategies to overcome this limitation and help improve risk assessments for both anthropogenic metal contamination, e.g., with copper, and geogenic background contamination, e.g., with nickel.

Copper reacts strongly with various functional groups present in soils and sediments, such as iron oxides and manganese oxides [1]. Localized deposits can be caused by

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Low-regret climate change adaptation in coastal megacities – evaluating large-scale flood protection and small-scale rainwater detention measures for Ho Chi Minh City, Vietnam

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Abstract. Urban flooding is a major challenge for many megacities in low-elevation coastal zones (LECZs), especially in Southeast Asia. In these regions, the effects of environmental stressors overlap with rapid urbanization, which significantly aggravates the hazard potential. Ho Chi Minh City (HCMC) in southern Vietnam is a prime example of this set of problems and therefore a suitable case study to apply the concept of low-regret disaster risk adaptation as defined by the Intergovernmental Panel on Climate Change (IPCC). In order to explore and evaluate potential options of hazard mitigation, a hydro-numerical model was employed to scrutinize the effectiveness of two adaptation strategies: (1) a classic flood protection scheme including a large-scale ring dike as currently constructed in HCMC and (2) the widespread installation of small-scale rainwater detention as envisioned in the framework of the Chinese Sponge City Program (SCP). A third adaptation scenario (3) assesses the combination of both approaches (1) and (2).

From a hydrological point of view, the reduction in various flood intensity proxies that were computed within this study suggests that large-scale flood protection is comparable but slightly more effective than small-scale rainwater storage: for instance, the two adaptation options could reduce the normalized flood severity index (I_{NFS}), which is a measure combining flood depth and duration, by 17.9 % and 17.7 %, respectively. The number of flood-prone manufacturing firms that would be protected after adaptation, in turn, is nearly 2 times higher for the ring dike than for the Sponge City approach. However, the numerical results also reveal that both response options can be implemented in parallel, not only without reducing their individual effectiveness but also complementarily with considerable added value. Additionally, from a governance perspective, decentralized rainwater storage conforms ideally to the low-regret paradigm: while the existing large-scale ring dike depends on a binary commitment (to build or not to build), decentralized small- and micro-scale solutions can be implemented gradually (for

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Land cover change impact on urban flood modeling (case study: *Upper Citarum watershed)*

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Abstract. The upper Citarum River watershed utilizes remote sensing technology in Geographic Information System to provide information on land coverage by interpretation of objects in the image. Rivers that pass through urban areas will cause flooding problems causing disadvantages, and it disrupts community activities in the urban area. Increased development in a city is related to an increase in the number of population growth that added by increasing quality and quantity of life necessities. Improved urban lifestyle changes have an impact on land cover. The impact in over time will be difficult to control. This study aims to analyze the condition of flooding in urban areas caused by upper Citarum watershed land-use change in 2001 with the land cover change in 2010. This modeling analyzes with the help of HEC-RAS to describe flooded inundation urban areas. Land cover change in upper Citarum watershed is not very significant; it based on the results of data processing of land cover has the difference of area that changed is not enormous. Land cover changes for the floods increased dramatically to a flow coefficient for 2001 is 0.65 and in 2010 at 0.69. In 2001, the inundation area about 105,468 hectares and it were about 92,289 hectares in 2010.

1. Introduction

Land cover change is dynamic process-taking place on the biophysical surfaces that have taken over a period and space is of enormous importance in natural resource studies. Land cover change dynamics are substantial elements for monitoring, evaluating, protecting and planning for earth resources. Land cover changes are the major issues and challenges for the eco-friendly and sustainable development for the economic growth of any area.

Land cover change is the conversion of open area to area woke indicated it would decrease catchment areas. Nowadays, the efforts to tackle the incident are still conventional runoff to flow quickly into the body of the river flow through the efforts of normalization techniques. Such shunt and water bodies [1]. Social and economic development drives land use and land cover changes, which have potentially enormous impacts on water resources. Changes in land use and land cover affect the partitioning of precipitation through the vegetation and soil into the main water balance components of interception, infiltration, evapotranspiration; surface runoff and groundwater recharge [2]. Land cover is an important determinant of Eco hydrologic processes in watershed systems. Continued urbanization changes the very nature of Eco hydrological regimes of watersheds and increases their vulnerability to flooding, soil loss, and water pollution [3].

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Flood Modelling Using Integration of Multi-data Analysis and HEC-RAS Model in Mata Allo River, Sulawesi

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Abstract. The amount of rainfall in a watershed with steep slopes, small cross-sectional areas, and less water catchment areas. This will cause an increase in water discharge in the river which can cause flooding. These characteristics can be found in Mata Allo River, Enrekang Regency. To identify the most flood-hit areas, the simulating model can be done utilizing the HEC-RAS program. Use of Satellite Imagery Data such as Sentinel-2 for extracting land use data information, and Sentinel-1 for data extraction of actual water bodies/rivers. The analysis is carried out by integrating the interpretation results from multi-sensor images with the results of modeling the flood inundation area using HEC-RAS. Based on the analysis results, the land use classification accuracy is 82.9% for Sentinel-2 data using the random forest algorithm. While for the actual extraction of water bodies using Sentinel-1 imagery was 89.6%. Approaching the threshold value between water and non-water bodies is taken using -13.39. The inundation area in the study area reached 87.66ha at the largest discharge model. The most affected land use after integrating each data is built-up land, most of which are settlements covering an area of 47.26ha.

1 Introduction

The territory of Indonesia is located in a wet tropical climate zone with quite high rainfall [1]. If detailed, about 80 percent of disasters in Indonesia are classified as hydrometeorological disasters such as floods, landslides, and hurricanes. Floods require serious attention from various parties because they contribute 37 percent of 143 of all disasters that occur nationally [2]. Floods occur when the volume of water flowing in drainage channels or rivers exceeds the flow capacity and absorption capacity of the surrounding dry land [3], [4]. Every year, the intensity and area of flood areas continue to increase due to environmental damage caused by humans, so the surface runoff rate increases, and the area of water catchment area decreases, which almost occurs in all watersheds in Indonesia. [5], [6]. One of the efforts to reduce the risk of flood disasters is flood spatial data management. With spatial flood information, decision-making in spatial planning for affected areas will be easier.

The Mata Allo River which passes through Enrekang Regency is one of the contributors to floodwater runoff yearly when there is an increase in rain intensity [7]. One of the causes of this flood is the change in land use in the upstream area of the river [8]. The area that is always affected is the City of Enrekang in the Juppandang district. Almost every year the area experiences floods with different flood intensities. One of the major flood events occurred on April 29, 2019, which caused the City of Enrekang to be flooded [2].

Spatial modeling in mapping flood hazard and vulnerability simulating the coverage of inundation areas and their potential impacts [9]. Integrating spatial data, such as remote sensing data [10] is widely used, because the additional information obtained from remote sensing data will strengthen the results and sharpen the spatial information of the analysis results carried out [11]–[13]. The lack of spatial data that provides information about the condition of the area that has the potential to be affected by flooding will cause gradual losses when a flood disaster occurs again. So that a need for spatial information on flood disaster areas that can be a reference or reference in disaster mitigation activities. Seeing the dynamics of the development of hydrological studies, especially on the phenomenon of urban flooding, now the development of the study is leading to a spatial (spatial) based study. Spatial-based studies cannot be separated from the role of Geographic Information Systems (GIS) as a supporting tool.

Moreover, the function of GIS can present a form of modeling of a hydrological phenomenon and the phenomenon of flooding in urban areas [14], [15]. Spatial modeling can be done by utilizing Geographic Information Systems (GIS) and Remote Sensing (RS) as information providers in the spatial modeling input. One of the programs in flood modeling is the HEC-RAS program. Using this program, the flood inundation area can be simulated based on the river discharge at the time of the flood [16], [17].

In this study, we approach the integration of multi-sensor images (optical and radar) on flood modeling

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B.3. IBER

CG9. B3

1. Descripción

Iber es un modelo numérico de simulación de flujo turbulento en lámina libre en régimen nopermanente, y de procesos medioambientales en hidráulica fluvial, desarrollado en colaboración por el Grupo de Ingeniería del Agua y del Medio Ambiente, GEAMA (Universidad de A Coruña, UDC) y el Instituto FLUMEN (Universitat Politècnica de Catalunya, UPC, y Centro Internacional de Métodos Numéricos en Ingeniería, CIMNE), en el marco de un Convenio de Colaboración suscrito entre el CEDEX y la Dirección General del Agua. El modelo Iber surgió inicialmente como respuesta al interés mostrado por el Centro de Estudios Hidrográficos del CEDEX en disponer de una herramienta que facilite la aplicación de la legislación sectorial vigente en materia de aguas, especialmente en los requerimientos derivados de la Directiva Marco del Agua, la Instrucción de Planificación Hidrológica, la Directiva de Inundaciones o el Plan Nacional de Calidad de las Aguas.

El rango de aplicación de Iber abarca la hidrodinámica fluvial, la simulación de rotura de presas, la evaluación de zonas inundables, el cálculo de transporte de sedimentos y el flujo de marea en estuarios. El modelo Iber consta actualmente de 3 módulos de cálculo principales: un módulo hidrodinámico, un módulo de turbulencia y un módulo de transporte de sedimentos.

Iber se desarrolló a partir de 2 herramientas de modelización numérica bidimensional ya existentes, Turbillón y CARPA, ambas con el método de volúmenes finitos, que fueron integradas en un único código ampliado con nuevas capacidades. El modelo Iber se encuentra en continuo desarrollo. Es, por tanto, un modelo vivo, abierto fácilmente a mejoras o adaptaciones. Entre las líneas prioritarias de desarrollo del modelo se encuentran: cálculos hidrológicos distribuidos, modelos de calidad de agua o evaluación del hábitat fluvial entre otros.

Las principales investigaciones en las que se ha usado IBER recientemente son Cea et al., 2023; García-Alén et al., 2023; García-Feal et al., 2018; Legarda et al., 2023; Lopéz-Chacón et al., 2023 y Mori-Sánchez et al., 2023.

2. Características técnicas

Programa	Iber		
Versión	3.30	Año	2022
Tipología	Modelación hidrológica		
Capacidades del programa	Iber es un modelo matemático bidimensional para la simulación del flujo en lámina libre y procesos de transporte en ríos y estuarios. El modelo Iber consta de un módulo hidrodinámico que permite la simulación bidimensional de cauces (y en consecuencia posibilita la definición de zonas inundables, la delimitación de vías de intenso desagüe o en general la zonificación del Dominio Público Hidráulico), un módulo de turbulencia y un módulo de transporte sólido por arrastre de fondo y en suspensión para la cuantificación de procesos de erosión y sedimentación.		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	Water and Environmental Engineering Group, GEAMA (University of A Coruña), the Flumen Institute (Polytechnic University of Catalonia, UPC, and International Center for Numerical Methods in Engineering, CIMNE), EPhysLab laboratory from University of Vigo and the the Centre for Hydrographic Studies of CEDEX		
Web	https://www.iberaula.es		

3. Ejemplos de trabajos científicos

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Using integrated hydrological-hydraulic modelling and global data sources to analyse the February 2023 floods in the Umbeluzi catchment (Mozambique)

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Abstract. On 9-13 February 2023 an intense flood event took place in the province of Maputo (Mozambique), resulting in severe damage to agricultural lands and transport infrastructure, and with serious consequences for the population. In the district of Boane, located a few kilometres downstream of the Pequenos Libombos dam, the flood destroyed many food crops as well as two bridges linking the district to Maputo, thus affecting the food security of the population. These events are quite frequent in this region, making necessary the delineation of improved flood hazard maps and the development of new flood risk management plans. We reproduce this flood event with a high resolution integrated hydrologic-hydraulic model fed with freely available global data sources, using a methodology that can be easily reproduced in other data-scarce regions. The model results are validated with observed estimations of the inflow to the Pequenos Libombos reservoir, with water marks left by the flood in the district of Boane, and with a Sentinel-1 image taken during the recession of the flood. We analyse the effect of the Pequenos Libombos reservoir on the flood hazard, which was subject to debate amongst the affected population and in the media. The results obtained show that integrated hydrologic-hydraulic models based on the two-dimensional shallow water equations, combined with global databases, are currently able to reliably reproduce extreme flood events in data-scarce basins, and are therefore very useful tools for the development of flood management plans in these regions.

1 Introduction

As with many other African countries, Mozambique is highly exposed to the impact of floods and to the effects of climate change (Revilla-Romero et al. 2015; World Bank, 2019). This is mainly due to the high vulnerability of its communities, combined with the extreme rainfalls produced by the tropical storms and cyclones that occur on its coastline on average every two years (WMO, 2019). Moreover, Mozambique's population is forecast to grow from 30 million to 65 million over the next 30 years, and will concentrate near rivers, lakes and the coastline, thus increasing the exposure of these populations to the impact of floods. In light of this, Mozambique has made significant efforts in recent years to put in place flood risk evaluation and mitigation measures.

The heavy rains that occurred in southern Mozambique between 6 and 15 February 2023 resulted in local rainfall depths of 350 mm, causing widespread flooding and considerable damage, especially in the city of Maputo and its neighbourhood. According to the data provided by the National Institute for Disaster Risk Reduction and Management (INGD), as of 17 February, 43,426 people has been affected by the floods, with 16,600 people displaced and 10 deaths (OCHA, 2023). The district of Boane, located downstream of the Pequenos Libombos (PL) dam and crossed by the waters of the Umbeluzi river and its tributary Movene, was the most affected part of the province. With a very flat topography, many neighbourhoods in this area were wholly inundated and isolated, given that road traffic was interrupted on the EN2 National Road that connects the city of Matola to the village of Boane. The Mazambabine and Boane bridges were submerged and the drinking water treatment plant was disrupted, resulting in significant cuts in water supply to the population. Upstream of the PL dam, the steel

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Research papers

Joint assimilation of satellite soil moisture and streamflow data for the hydrological application of a two-dimensional shallow water model

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ARTICLE INFO

Keywords:
Hydrodynamic modelling
Iber+
Flood forecasting
Tempered particle filter
Shallow water equations
Data assimilation

ABSTRACT

Data assimilation (DA) in physically-based hydrodynamic models is conditioned by the difference in temporal and spatial scales of the observed data and the resolution of the model itself. In order to use remote sensing data in small-scale hydrodynamic modelling, it is necessary to explore innovative DA methods that can lead to a more plausible representation of the spatial variability of the parameters and processes involved. In the present study, satellite-derived soil moisture and in situ-observed streamflow data were jointly assimilated into a high-resolution hydrological-hydrodynamic model based on the Iber software, using the Tempered Particle Filter (TPF) for the dual estimation of model state variables and parameters. Twelve storm events occurring in a 199 km^2 catchment located in NW Spain were used for testing the proposed approach. A 3-step procedure was followed: (1) sensitivity analysis of the model parameters; (2) joint assimilation of soil moisture and discharge data to estimate correlations between observations and model parameters; (3) joint assimilation of soil moisture and discharge data using an initial set of particles and parameter standard deviations derived from prior information. The numerical model correctly reproduces the observed data, with an average Nash-Sutcliffe efficiency (NSE) value of 0.74 over the 12 events when the prior information is used. The approach described is shown to be most efficient with storm events that produce isolated peak discharges.

1. Introduction

The inherent uncertainty of hydrological modelling (Blöschl et al., 2019) can be reduced by assimilating independent observed data, such as satellite observations or data from gauging stations (Liu and Gupta, 2007). Data assimilation (DA) has been traditionally used for uncertainty quantification and probabilistic forecasting in climate and ocean models. More recently, DA has also been applied in the field of hydrology to improve the accuracy of model predictions, assimilating variables such as soil moisture and streamflow (Gavahi et al., 2020; Hostache et al., 2020; Moradkhani et al., 2005; Xu et al., 2020), and has proved to be a powerful approach to real-time forecasting by updating the model state variables and parameters when new observations become available (Hostache et al., 2018; Moradkhani et al., 2019). The spatiotemporal resolution of remote sensing data is particularly appropriate for assimilation into large-scale hydrological and climate models (Abbaszadeh et al., 2018; Azimi et al., 2020; Lievens et al., 2017). On the other hand, observations at in situ gauging stations are still the most commonly used ones in hydrodynamic modelling (Jafarzadegan et al., 2021), with the inconvenience that such data are scarce in their distribution in terms of space. This is so because the spatial and temporal resolutions of satellite data are often too low to allow for their integration into high-resolution small-scale hydrodynamic models. Due to the rapid dynamics of some flood events in small and medium-scale catchments, it is not possible to work with a time resolution longer than one day, and, especially in flood extent analysis, with spatial resolutions much greater than the resolution of the numerical model itself. Since satellite products are still not always able to provide these temporal and spatial resolutions, the integration of these data into hydrodynamic models tends to be rather recent, and usually focused on large rivers (Brêda et al., 2019; Dasgupta et al., 2021a, 2021c; Meyer Oliveira et al., 2021; Wongchuig-Correa et al., 2020).

Most DA frameworks are based on the Kalman Filter and its variants (Annis et al., 2022; Jafarzadegan et al., 2021; Muñoz et al., 2022; Revilla-Romero et al., 2016; Wongchuig-Correa et al., 2020). These techniques do not require a very large number of model simulations,

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water

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Article

An Accelerated Tool for Flood Modelling Based on Iber

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Abstract: This paper presents Iber+, a new parallel code based on the numerical model Iber for two-dimensional (2D) flood inundation modelling. The new implementation, which is coded in C++ and takes advantage of the parallelization functionalities both on CPUs (central processing units) and GPUs (graphics processing units), was validated using different benchmark cases and compared, in terms of numerical output and computational efficiency, with other well-known hydraulic software packages. Depending on the complexity of the specific test case, the new parallel implementation can achieve speedups up to two orders of magnitude when compared with the standard version. The speedup is especially remarkable for the GPU parallelization that uses Nvidia CUDA (compute unified device architecture). The efficiency is as good as the one provided by some of the most popular hydraulic models. We also present the application of Iber+ to model an extreme flash flood that took place in the Spanish Pyrenees in October 2012. The new implementation was used to simulate 24 h of real time in roughly eight minutes of computing time, while the standard version needed more than 15 h. This huge improvement in computational efficiency opens up the possibility of using the code for real-time forecasting of flood events in early-warning systems, in order to help decision making under hazardous events that need a fast intervention to deploy countermeasures.

Keywords: flood; numerical simulation; shallow water equations; Iber+; benchmark; CUDA; OpenMP; finite volume

1. Introduction

Floods are a type of natural disaster that have affected human activity throughout history. In recent years, these phenomena have become more frequent and intense due to climate change [1,2]. The development of numerical tools that are able to simulate these events has become essential. These tools must be accurate, in order to provide useful data, as well as computationally efficient, to be able to obtain results in reasonable computational times. The information provided by the numerical models should help decision makers to design resilient structures, as well as to estimate the intensity of an imminent extreme event in order to implement countermeasures that avoid or mitigate the economic and human losses.

Iber [3] is a numerical model that solves the two-dimensional (2D) depth-averaged shallow water equations with an unstructured explicit finite volume solver. In addition to the hydraulic module,

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Research papers

Exploring the effects of catchment morphometry on overland flow response to extreme rainfall using a 2D hydraulic-hydrological model (IBER)

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ARTICLE INFO

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Hydrological Modelling
Flood risk management
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Catchment shape
Watershed
Drainage basin

ABSTRACT

The hydrological response of a catchment to heavy rainfall is determined by many environmental and climatic variables, including the catchment size, shape and morphology, land use, soil depth and type, and prevailing weather conditions. As a result of the interaction between these variables, the hydrological response of a catchment is unique and can be highly variable depending on the antecedent conditions and characteristics of the meteorological event. This complexity makes it problematic to identify the significance of individual drivers of hydrological response. Here, the role of catchment morphometry in controlling hydrological response was explored by creating abstract catchments so the impact of morphometry could be isolated from the confounding impacts of other parameters that are known to impact hydrological response and flood risk. A procedure was developed to select catchments that represent a range of global morphometries, and these were then simplified and treated as synthetic catchments. A coupled hydrological-hydraulic model (IBER) was used to model the hydrological response to 4 constructed rainfall events (one magnitude, four distribution types), consistent across all catchments, and representing torrential rainfall (60 mm h^{-1}). Designed rainfall were equally distributed across the whole area in each catchment. Catchments were statistically partitioned into groups based on their morphometry (i.e. shape, slope, size, hypsometric slope, etc) and distinct hydrological responses were observed between groups. Catchment size was significantly related to peak flow or lag time with a power law, in line with previous studies, and relationships with other morphometric parameters were stronger when catchments were assessed in separate size groupings. Area and the average slope of catchments were key parameters in controlling peak flow magnitudes. Variation in hydrological response was much greater between catchments for the same rainfall event, than within the same catchment for different rainfall events. The results suggest that hydrological response can be broadly characterised using morphometric variables, increasingly obtainable using Earth Observation methods, providing potential benefits for flood prediction, flood alerts, and focusing where more detailed flood modelling is required.

1. Introduction

River flooding is a persistent, pervasive, and dangerous natural hazard, with severe global impacts (Dottori et al., 2018, Merz et al., 2021). Approximately 33 % of the total global land surface is susceptible to flooding (Pradhan, 2010) and the number of people affected by flooding has significantly increased since 1870 (Paprotny et al., 2018). Changes in hydrology due to land-use and ongoing climate change have increased flood risk in many areas, causing serious social, economic and environmental issues (Quintero et al., 2018, Huizinga et al., 2017). For example, both the frequency and intensity of rainfall has increased over the last three decades globally (Kundzewicz et al., 2013, Milly et al., 2005, Brakenridge et al., 2004) and Arnell and Gosling (2016) argue that by 2050, floods with return periods of 100 years could be at least twice as frequent across 40 % of the World, increasing global flood risk by 187 %.

Floods are hydrological responses to hydrometeorological circumstances such as extreme rainfall, cyclones or thunderstorms (Villarini and Smith, 2010, Ghimire and Ferreira, 2016), but their timing and frequency is dependent on a complex interplay between physical and hydrological factors (Schumm et al., 1987). Hydrological response also depends on the rainfall event type and characteristics, such as the

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water

MDPI

Article

Combining Synthetic and Observed Data to Enhance Machine Learning Model Performance for Streamflow Prediction

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Abstract: Machine learning (ML) models have been shown to be valuable tools employed for streamflow prediction, reporting considerable accuracy and demonstrating their potential to be part of early warning systems to mitigate flood impacts. However, one of the main drawbacks of these models is the low precision of high streamflow values and extrapolation, which are precisely the ones related to floods. Moreover, the great majority of these models are evaluated considering all the data to be equally relevant, regardless of the imbalanced nature of the streamflow records, where the proportion of high values is small but the most important. Consequently, this study tackles these issues by adding synthetic data to the observed training set of a regression-enhanced random forest model to increase the number of high streamflow values and introduce extrapolated cases. The synthetic data are generated with the physically based model Iber for synthetic precipitations of different return periods. To contrast the results, this model is compared to a model only fed with observed data. The performance evaluation is primarily focused on high streamflow values using scalar errors, graphically based errors and errors by event, taking into account precision, over- and underestimation, and cost-sensitivity analysis. The results show a considerable improvement in the performance of the model trained with the combination of observed and synthetic data with respect to the observed-data model regarding high streamflow values, where the root mean squared error and percentage bias decrease by 23.1% and 38.7%, respectively, for streamflow values larger than three years of return period. The utility of the model increases by 10.5%. The results suggest that the addition of synthetic precipitation events to existing records might lead to further improvements in the models.

Keywords: machine learning; physically based; Iber; streamflow; high values; synthetic; floods; regression-enhanced random forest

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1. Introduction

Floods are natural hazards that have the highest impact on the population worldwide [1–3]. Among these, flash floods have the potential to be extremely costly in terms of material damage and fatalities [4]. They usually occur suddenly as a product of intense rainfall in a small catchment with considerable slopes [5,6]. The frequency of flash floods has increased in recent years as a result of more common high-intensity rainfall and larger urban areas [7,8]. One of the main tools to prevent and mitigate material and human losses caused by floods is the early warning system (EWS) [9], which is capable of issuing an alert in case hazardous streamflow is expected. One of the key components of the EWS is a streamflow prediction model. In that regard, two main approaches have been the employment of physically based models [10,11] and machine learning (ML) models, which in recent decades have become popular among hydrologists [12]. Both models have

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Application of the Iber Two-Dimensional Model to Recover the Water Quality in the Lurín River

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Abstract: The Lurín River is one of the main sources of water for the city of Lima. However, the discharge of domestic wastewater, the presence of dumps, and long periods of drought cause the deterioration of the water resource. In this study, *DO*, BOD_5, *E. coli*, *T*, *EC*, *TSS*, *U*, and *h* were monitored at 13 monitoring points spread over 20 km of river influence. This information was used to calibrate the parameters of K_{dbo}, K_{aire}, K_{dos}, and K_{dec} in the Iber two-dimensional numerical model, obtaining values of 0.55 d^{-1}, [4.84 d^{-1}–80.65 d^{-1}], 10 g O_2 $m^{-2}d^{-1}$, and [1.49 d^{-1}–15.42 d^{-1}], respectively, with efficiencies ranging from "very good" to "satisfactory". In the hydraulic model, a discretization of the channel, banks, and plains of 3, 5, and 7 m, respectively, was considered, resulting in a computational calculation time of 4 days in each simulation. The greatest contamination occurs in July at km 5 + 400 up to the Pan-American bridge. Therefore, it is proposed to recover the river by optimizing the San Bartolo Wastewater Treatment Plant (WWTP) and a new WWTP in Pachacámac to avoid diffuse contamination, with discharge flows of 0.980 m^3s^{-1} and 0.373 m^3s^{-1}, respectively, and 4 mg L^{-1}, 15 mg L^{-1} and 1000 NMP/100 mL for *DO*, BOD_5, and *E. coli*, respectively.

Keywords: biochemical oxygen demand; *Escherichia coli*; Iber two-dimensional numerical model; dissolved oxygen

Citation: Mori-Sánchez, O.L.; Ramos-Fernández, L.; Lluén-Chero, W.E.; Pino-Vargas, E.; Flores del Pino, L. Application of the Iber Two-Dimensional Model to Recover the Water Quality in the Lurín River. *Hydrology* **2023**, *10*, 84. https://doi.org/10.3390/hydrology10040084

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1. Introduction

The available water per capita in the world is reduced because of the increase in population, dumping of waste and chemicals from agricultural runoff, livestock, industrial and mining activities, and inadequate management of solid waste, which cause water shortages and deterioration of its quality. Contamination, without sufficient treatment, in rivers is a great concern, mainly because rivers are the source of water for domestic consumption; it is important to determine the quality of the water in rivers.

The Lurín river basin, which originates in the Andes Mountains, is located on the central coast of Peru, which has approximately two million inhabitants. Its climate is arid with scarce rainfall and inadequate management of water sources, leading to the inefficient development of agriculture and livestock, the main economic activities in the mentioned watershed [1]. Likewise, there is an accelerated process of unplanned urbanization, strong pressure for land and a risk of becoming a new industrial park. However, areas used for agriculture are still preserved, with tourism and archaeological potential resources, but with high poverty rates. In its lower section, the river is subject to important pressures derived from the extraction of water resources, the discharge of urban wastewater (treated and untreated), garbage disposal, livestock, and agricultural drainage. All this leads to an increasing scarcity of water and deterioration of its quality, negatively impacting aquatic ecosystems, and these factors are exacerbated during drought periods [2].

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Mori-Sánchez, O.L., Ramos-Fernández, L., Lluén-Chero, W.E., Pino-Vargas, E. y Flores del Pino, L. (2023). Application of the Iber Two-Dimensional Model to Recover the Water Quality in the Lurín River. Hydrology. [Online]. 10 (4). p.p. 84. http://dx.doi.org/10.3390/hydrology10040084

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B.4. MODFLOW

CG9. B4

1. Descripción

ModFlow es un modelador de flujo por diferencias finitas desarrollado por el Servicio Geológico de Estados Unidos (USGS). Se basa en un código fuente que resuelve mediante interacciones la ecuación de flujo de agua subterránea. Se emplea en hidrogeología para simular el flujo subterráneo de cualquier acuífero. El programa es de código abierto y puede usarse en Linux, Windows o macOS X.

Desde que el modelo original fue desarrollado en los años 80, el Servicio Geológico de EEUU lo considera como un código estándar para las simulaciones de acuífero (la primera versión data de 1984). La versión actual que data del año 2022 es la versión ModFlow 6 que ya desde versiones anteriores cuenta con un marco robusto para la integración de capacidades de simulación adicionales que mejoran su alcance original. ModFlow cuenta, por tanto, con una amplia familia de programas relacionados que incluye capacidades para simular sistemas acoplados de agua subterránea-agua superficial, transporte de soluto, flujo de densidad variable (incluyendo agua salada), compactación del sistema acuífero, etc.

ModFlowes un software ampliamente utilizado en las ciencias naturales y en la investigación. Las principales investigaciones en las que se ha usado recientemente son An et al., 2022; Aslam et al., 2022; Chowdhury y Rahnuma, 2023; Costa et al., 2023; El-Haddidy y Morsy, 2022 y Shikha-BagemChaleh et al., 2023.

2. Características técnicas

Programa	MODFLOW		
Versión	6.4.1	Año	2022
Tipología	Modelación hidrológica		
Capacidades del programa	Programa de modelización de flujo por diferencias finitas que consiste en un código fuente que resuelve mediante interacciones la ecuación de flujo del agua subterránea. Modflow se considera un estándar internacional para simular y predecir las condiciones del agua subterránea y las interacciones aguas subterráneas / aguas superficiales		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	U.S. Geological Survey (USGS)		
Web	https://www.usgs.gov/software/modflow-6-usgs-modular-hydrologic-model		

3. Ejemplos de trabajos científicos

The current issue and full text archive of this journal is available on Emerald Insight at:
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Groundwater simulation in Dak Lak province based on MODFLOW model and climate change scenarios

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Abstract

Purpose – Groundwater plays a critical part in both natural and human existence. When surface water is scarce in arid climates, groundwater becomes an immensely valuable resource. Dak Lak is an area that frequently lacks water resources for everyday living and production, and the scarcity of water resources is exacerbated during the dry season. As a result, it is critical to do study and understand about groundwater to meet the region's water demand. This study aims to extend the use of the MODFLOW model for groundwater simulation and assess the overall groundwater reserves and water demand in the highland province Dak Lak.

Design/methodology/approach – The MODFLOW model is used in this work to compute and analyze the flow, prospective reserves of groundwater from which to plan extraction and estimate groundwater variation in the future.

Findings – The application of the MODFLOW model to Dak Lak province demonstrates that, despite limited data, particularly drilling hole data for subterranean water research, the model's calculation results have demonstrated its reliability and great potential for use in other similar places. The use of the model in conjunction with other data extraction modules is a useful input for creating underground flow module maps for various time periods. The large impact of recharge and evaporation on groundwater supplies and water balance in the research area is demonstrated by simulations of climate change scenarios RCP4.5 and RCP8.5.

Originality/value – None of the studies has been done previously to analyze water resources of Dak Lak and the scarcity of water resources is exacerbated during the dry season. Therefore, this study will provide useful insights in the water resource management and the conservation of Dak Lak. The groundwater in Dak Lak can meet the area's water demand, according to the results obtained and water balance in the study area. However, the management of water resources and rigorous monitoring of groundwater extraction activities in the area should receive more attention.

Keywords MODFLOW, Groundwater, Dak Lak, Climate change scenarios

Paper type Research paper

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Article

Hydrological Modeling of Aquifer's Recharge and Discharge Potential by Coupling WetSpass and MODFLOW for the Chaj Doab, Pakistan

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Abstract: The estimation of the groundwater (GW) potential in irrigated areas is crucial for the sustainable management of water resources in order to ensure its sustainable use. This study was conducted in a selected area of the Chaj doab, Punjab, Pakistan, to quantify the impacts of the pumping and the recharge on the aquifer therein. To that end, a groundwater flow model (MODFLOW) and a groundwater recharge model (WetSpass) were coupled to assess the conditions of the aquifer. The model was calibrated manually on twelve-year data (2003–2014) against the observed groundwater levels, and it was validated with five-year data (2015–2019). Three main scenarios (divided into ten subscenarios) were simulated for the future prediction of the groundwater: Scenario-I (to assess the impact of the pumping if the prevailing conditions of the years from 2003 to 2019 were to continue until 2035); Scenario-II (to assess the impact of the pumping on the aquifer by increasing the pumping capacity by 25, 50, 75, and 100% for the coming 10 years); and Scenario-III (to assess the impact on the aquifer of the decrease in the average groundwater recharge from the river by 50% by following the same pumping trend). The Scenario-I results show that there would be an 18.1 m decrease in the groundwater table at the end of the year 2035. The Scenario-II results predict decreases in the water table by 2.0, 5.5, 9.8, and 14.3 m in the year 2029 as a result of increases in the pumping capacity of 25, 50, 75, and 100%, respectively. The results of Scenario-III show that, with the decrease in the recharge from the rainfall, there would be a 0.7 m decrease in the water table, and that, from open-water bodies, there would be a 2.4 m decrease in the water table. These results are very helpful for determining the recharge and discharge potential of the aquifer.

Keywords: groundwater budgeting; irrigation water management; WetSpass-M; groundwater flow modeling; coupling of hydrological models; MODFLOW

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1. Introduction

Water availability is essential for meeting agricultural, domestic, and industrial needs. In the past few decades, the burden on the groundwater resources of Pakistan has increased because of their unchecked, unguided, and unregulated exploitation [1]. At a global level, about 750–800 billion cubic meters (BCM) of groundwater is being consumed for agriculture [2,3]. Shortfalls in the surface water is the reason for the increasing use of groundwater [4]. The supply of surface water has decreased significantly in recent years, and the demand for groundwater has also increased proportionately [5]. Groundwater resource management in the Chaj doab, Pakistan, and especially in the Khadir canal subdivision, is necessary for improving agriculture and protecting the ecosystem, as well as for biodiversity [6].

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Groundwater contaminant transport modeling using MODFLOW and MT3DMS: a case study in Rajshahi City

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ABSTRACT

Rapidly growing urbanization and industrialization processes including man-made activities result in groundwater contamination that becomes unsafe for human use. In this study, the groundwater flow and contaminant migration through aquifers in Rajshahi City were modeled using MODFLOW and MT3DMS codes. ModelMuse, a graphical user interface (GUI), is used to run the codes and the hydrological and geological data of the region are used as the input parameters for the model. The travel distance of five selected contaminants such as chromium (Cr), copper (Cu), manganese (Mn), lead (Pb), and zinc (Zn), from the source (e.g. landfill site), were simulated corresponding to travel times of 1, 3, 5, 10, 15, 20, and 50 years. The study results showed that the migration distance of the contaminants increases over time and follows a logarithmic trend. Among the contaminants, the model-predicted results show that the concentration of Cr and Pb in the groundwater varies more than 90% from their standards over the period of 50 years, which suggests that these two pollutants are the prime contaminants polluting groundwater in the coming future. This model can be used as an effective decision-making tool for the monitoring of groundwater contaminant transport for a specific location.

Key words: contaminant transport, groundwater modeling, MODFLOW, MT3DMS-USGS, Rajshahi City

HIGHLIGHTS

- Groundwater flows from the north to south of the RCC area.
- Contaminant travel time versus distance relationship follows a logarithmic trend.
- Cr, Pb, and Mn are three prime contaminants polluting groundwater in RCC.
- Ward numbers 14, 16, 17, and 18 of RCC are more susceptible to groundwater pollution.
- Affected area due to pollutants increases with increasing time.

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REPORT

Assessment of aquifer recharge and groundwater availability in a semiarid region of Brazil in the context of an interbasin water transfer scheme

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Abstract
Particularly in arid and semiarid areas, more and more populations rely almost entirely on imported water. However, the extent to which intentional discharge into transiting riversystems and unintentional leakage may be augmenting water resources for communities along and down gradient of the water transfer scheme has not previously been subject to research. The objective of this study was to assess both the potential of a large-scale watertransfer (WT) scheme to increase groundwater availability by channel transmission losses in a large dryland aquifer system (2,166 km²) in Brazil, and the capability of the receiving streams to transport water downstream under a prolonged drought. An integrated surface-water/groundwater model was developed to improve the estimation of the groundwater resources, considering the spatio-temporal variability of infiltrated rainfall for aquiferrecharge. Aquifer recharge from the WT scheme was simulated under prolonged drought conditions, applying an uncertainty analysis of the most influential fluxes and parameters. The annual recharge (66 mm/year) was approximately twice the amount of water abstracted(1990–2016); however, the annual recharge dropped to 13.9 mm/year from 2012 to 2016, a drought period. Under similar drought conditions, the additional recharge (6.89 × 106 m³/year) from the WT scheme did not compensate for the decrease in groundwater head in areas thatdo not surround the receiving streams. Actually, the additional recharge is counteracted by a decrease of 25% of natural groundwater recharge or an increase of 50% in pumping rate; therefore, WT transmission losses alone would not solve the issue of the unsustainable management of groundwater resources.

Introduction

Particularly in arid and semiarid areas of the world, more and more populations rely almost entirely on imported water (Davies et al. 1992). Despite their generally large engineering challenges and correspondingly high costs, interbasin water transfer schemes are becoming increasingly common and are increasing in ambition (Rollason et al. 2021). The largest future water transfer mega-projects are located in North America, Asia, and Africa with predicted total investment exceeding US$2.7 trillion (Shumilova et al. 2018). The scale of these supply-oriented solutions attests to the perceived magnitude of the needs and interests of the recipient economic centres (Gupta and van der Zaag 2008).

While there are many examples of water transfers that have brought socio-economic benefits to both the recipient and donor basins, studies are not uncommon in the literature describing negative impacts on donor and transit basins, particularly on marginal communities, who have surrendered rights to land and water (Rollason et al. 2021). However, the extent to which intentional discharge into transiting river systems and unintentional leakage may be augmenting water resources for communities along and down gradient of water transfer schemes has not previously been subject to research. These water transfer losses are of critical importance to water managers and may represent an unexpected windfall

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Research Paper

Expected spatio-temporal variation of groundwater deficit by integrating groundwater modeling, remote sensing, and GIS techniques ☆

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ABSTRACT

For the last 6 decades, the Nile Valley region has been subjected to expanding reclamation, advancing agricultural and human activities. Extreme changes in the groundwater regime and land cover have been detected. Evaluation and mapping of groundwater and its controlling factors as important environmental factors have been assessed and managed based on their Spatio-temporal distribution and effect on the hydrologic properties. Visual MODFLOW and GIS database modeling are applied to simulate and predict the future aquifer response due to increased pumping rates to match the continuous need for water resources. Two pumping scenarios are proposed. The first scenario assumes that the current extraction rates continue without modification over the next 50 years. The second scenario assumes to increase the pumping rates by 50% from those of the first scenario. An obvious decline in groundwater heads is resulting in both scenarios. It reaches 20 m in the first scenario while it exceeds 30 m in the second one. Results obtained from the model have been merged with remote sensing data under GIS framework. GIS model using the weighted overlay approach is applied to produce the groundwater potentiality map, classified to five potential zones; very good, good, intermediate, poor, and very poor, the model showed that zone of very good recharge will decrease with time and disappear with increase pumping rate by 50% while the poor and very poor zones increase with time. There is a reciprocal relationship between the human and geological factors on the efficiency of the aquifer.

1. Introduction

Groundwater in the Quaternary aquifer in reclamation areas situated in the elevated desert lands, adjacent to the Nile Valley, is subjected to over-pumping to overcome the future demand of freshwater. The purpose of this study is to predict the effect of long-term pumping capacity and the impact of reclamation and urbanization on the cultivated lands and the potentiality of groundwater in the Quaternary aquifer at northwest of the Nile Valley (Fig. 1). The present work introduces a new approach by integrating groundwater flow modeling with remote sensing and GIS techniques to determine the availability and improve utilization of groundwater resources to meet future demands to expand reclamation, advancing agricultural and human activities. El Alfy (2014), Moneim et al. (2016), and Abdelhalim et al. (2019) have proved that groundwater modeling is an effective application for the management of groundwater resources.

Numerous studies have attempted to incorporate groundwater monitoring parameters derived from GIS-based remote sensing data, such as Elbeih (2014), Adewumi and Anifowose (2017), Bawallah, et al. (2020), Gaber et al. (2020) and Adusei et al. (2021).

1.1. Study area

1.1.1. Geological aspects

The study area lies west of the Nile River forming an elongated strip along the flood plain of the Nile River, that bounded by longitudes 28° and 29° 30′ E and latitudes 30° and 31° 30′ N (Fig. 1). Quaternary rock units cover the surface of the study area forming the cultivated flood plain distinguished into Holocene silt and clay,

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ORIGINAL ARTICLE

Planning for groundwater management using visual MODFLOW model and multi-criteria decision analysis, West–West Minya, Egypt

Samah Mahmoud Morsy[1]

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Abstract
This study presents a planning model to assist decision-makers in implementing proposed sustainable development policies based on the government's development schemes. It focuses on the exploitation of groundwater from the Eocene aquifer in the West–West Minya region in the Western Desert of Egypt as one of the new development areas. The visual MODFLOW model is applied to serve as a base model for the study area's local modeling and assess the impact of operating scenarios on the groundwater aquifer. An optimal scenario for groundwater sustainability is achieved by considering the water meter consumption in the newly reclaimed area with a value of 6 m^3/d for each acre to irrigate 3953.68 acres; the maximum drawdown of about 60 m is formed after 9700 days of simulation. The GIS multi-criteria analysis model is used to assess the impact of groundwater deficiency as a result of reclamation. Results of the groundwater model are merged as input layers in multi-criteria decision analysis, which include groundwater salinity, groundwater levels, aquifer transmissivity, and aquifer storativity. The prospective groundwater zones are categorized into most suitable (1584 km^2, 9.9%), suitable (4592 km^2, 28.7%), good (4784 km^2, 29.9%), moderate (1488 km^2, 9.3%), and unsuitable (3552 km^2, 22.2%). It is recommended to optimize levels of groundwater withdrawal from the current or future drilling wells to achieve a balance between the use and the protection of water potential.

Keywords Groundwater management · Groundwater modeling · Visual MODFLOW model · Multi-criteria decision analysis

Introduction

On a global scale, groundwater is the primary source of freshwater. It accounts for about one-third of freshwater withdrawals (Siebert et al. 2010; Famiglietti 2014). An estimated 2.5 billion people worldwide depend on groundwater for their use (Chakrabarti 2017). This condition is a fact in arid and semi-arid regions because of the scarcity of rainfall and the limitation of surface water masses which are sometimes even absent. Due to high population density, global climatic change, and seawater intrusion in coastal aquifers, the demand for groundwater resources is expected to increase by about 110 billion cubic meters per year (BCM/Y) (Alfy and Abdalla 2021); in addition to the compounded environmental effects of the Grand Ethiopian Renaissance Dam (GERD) as will reduce the flow of water in the Nile River between 11 and 19 billion m3 (BCM) (Yihdego et al. 2017). In Egypt, the surface water from the Nile River is a primary source of daily drinking water production about 22.1 million m^3 with 82.1% (HCWW 2017); and the groundwater is an integral part of its national policy where it is used for drinking, domestic, and industrial purposes. With the continuous deficiency of fresh water and the importance of groundwater, the Egyptian government started a new development project to reclaim 1.5 million acres to increase agricultural areas. Groundwater is the only source of irrigation water in the newly reclaimed areas; it is also a supplementary source of irrigation in the old, cultivated areas. Two main aquifer systems are relevant in Egypt. The first is the sandstones and gravels interbedded with clays aquifer system represented by Nile Valley and Delta, Nubian sandstone, coastal and Moghra systems. The second is the fissured and karstified aquifer system represented by limestone and hard igneous and metamorphic rocks (Hefny and Shata 2004; Alfy and Abdalla 2021).

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ORIGINAL ARTICLE

The effect of climate change on surface and groundwater resources using WEAP-MODFLOW models

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Abstract
In addressing management scenarios and climate changes, it is necessary to consider surface water and groundwater resources as an integrated system. In this context, the present research first simulates and evaluates surface water and groundwater simultaneously; then, it examines the possible effects of climate change on these water resources in the study area (Mahabad, Northwest of Iran). In the first stage, the WEAP-MODFLOW model was applied to a 10-year period (2006–2015) in order to take into account the interactions between surface water and groundwater and calibrate the amount of recharge and drainage from the aquifer. In the second stage, in order to study the effect of climate change on surface water and groundwater resources, we compared the micro-scale model outputs under the RCP4.5 scenario for different climate change models in the period 2021–2045. The results show that root-mean-square error (RMSE) and mean absolute error (MAE) scores are equal to 0.89 and 0.79 in unsteady conditions, respectively, which confirm the efficient performance of groundwater simulation. In addition, the results of the WEAP model based on MARE assessment criteria for calibration and validation modes are equal to 0.54 and 54.0, respectively. This finding provides evidence for the efficient performance of the simulation model. Once the interactions between groundwater and surface water were specified, the results R^2 and NS suggested that indices were equal to 0.62 and 0.59, respectively, for Mahabad hydrometric station. The efficient performance of the proposed model for runoff simulation was therefore confirmed. Owing to climate change in the study period, groundwater decreased by about 1.6–1.9 m. Moreover, the amount of runoff declined from 0.1 to 0.001 MCM/month in all months except December. Unless appropriate decisions are taken to improve groundwater and strategies are applied to reduce the effect of climate change, under the present conditions this region will suffer irreparable damages in the future.

Keywords Conjunctive use · WEAP-MODFLOW · Climate change · Mahabad aquifer

Introduction

Proper management of surface water resources (including dams and rivers) and groundwater resources requires paying special attention to all parameters of hydrologic balance. Water consumption management is vital in arid and semiarid regions. The agricultural sector is the largest consumer of water, accounting for about 70% of the consumption of fresh water resources (FAO 2017).

Water shortage and restriction of water resources is currently a major problem in Iran. Therefore, the role of water resource and consumption management is especially important due to an increasing demand for water. In addition, Iran is located in an arid and semiarid region. Population growth, urbanization and expansion of urban areas, and industrial and agricultural developments have led to an increased water demand (Hashemi et al. 2018; Ostad-Ali-Askari 2022). Under these circumstances, water resource management is crucial in order to maintain the balance between water demand and consumption (Kayhomayoon et al. 2021). Therefore, it is necessary to have a sound understanding of the natural behavior of the hydrological system in order to manage hydrological phenomena. Since surface water and groundwater resources are the two main systems for meeting water demand, it is necessary to take their capacities and limitations into consideration (Milan et al. 2023).

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B.5. SWMM

CG9. B5

1. Descripción

SWMM es un modelo dinámico de simulación de precipitaciones (StormWater Management Model) que se puede usar para un único acontecimiento o para realizar una simulación continua en un periodo más o menos amplio. El programa permite simular tanto la cantidad como la calidad del agua evacuada, especialmente ideado para alcantarillado urbano.

SWMM representa el comportamiento de un sistema de drenaje mediante una serie de flujos de agua y materia con una serie de módulos principales que componen un análisis medioambiental. Estos módulos son el de escorrentía, transporte y calidad. Este programa puede simular los procesos de lluvia-escorrentía, evaporación, infiltración y conexión del agua subterránea con las raíces, zanjas, tuberías, etc.

Este software ha sido desarrollado por la División de Abastecimiento de Agua y Recursos Hídricos de la Agencia de Protección Ambiental de los Estados Unidos (EPA). Su primera versión data del año 1971 y ha sido mejorada desde entonces en múltiples aspectos. La versión 5 es la última que se ha desarrollado de SWMM y se trata de un código abierto y de dominio público que puede descargarse desde la página web de la EPA y ha sido elaborada por el Laboratorio Nacional de Investigación sobre Riesgos de la propia agencia medioambiental de Estados Unidos.

Las principales investigaciones en las que se ha usado SWMM recientemente son Fava et al., 2022; Hossain et al., 2019; Iffland et al., 2021; Weggemans et al., 2023; Xiao y Vasconcelos, 2022; Yang et al., 2023 y Yang et al., 2023.

2. Características técnicas

Programa	SWMM		
Versión	5.2.4	Año	2023
Tipología	Modelación hidrológica		
Capacidades del programa	SWMM es un modelo dinámico de simulación de calidad de agua hidrológica e hidráulica. Se emplea para la simulación de un evento único o continuo (a largo plazo) de la cantidad y calidad de escorrentía de áreas principalmente urbanas. El componente de escorrentía se calcula en una serie de subcuencas que reciben precipitación y generan cargas de escorrentía y de contaminantes. El programa realiza un seguimiento de la velocidad de flujo, su profundidad y calidad de agua en cada tubería y canal durante un periodo de simulación formado por varios pasos de tiempo.		
Sistema operativo			
	Windows (32 y 64 bits)		
Tipo de sistema (arquitectura)	32 y 64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	United States Environmental Protection Agency (EPA)		
Web	https://www.epa.gov/water-research/storm-water-management-model-swmm		

3. Ejemplos de trabajos científicos

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Article

Linking Urban Floods to Citizen Science and Low Impact Development in Poorly Gauged Basins under Climate Changes for Dynamic Resilience Evaluation

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Abstract: Cities must develop actions that reduce flood risk in the face of extreme rainfall events. In this study, the dynamic resilience of the Gregorio catchment (São Carlos, Brazil) was assessed. The catchment lacks environmental monitoring and suffers from recurrent floods. The resilience curves were made considering the water depth in the drainage system as the performance index, obtained by simulations with SWMM and HEC-RAS. The calibration of the flood extension was performed using citizen science data. The contribution to increasing the dynamic resilience by implementing decentralized low impact development (LID) practices was also evaluated. For this purpose, bioretention cells were added to the SWMM simulations. The resilience curves were then calculated for the current and future climate scenario, with and without LID, for return periods of 5, 10, 50, and 100 years and duration of 30, 60, and 120 min. Intensity–duration–frequency curves (IDFs) updated by the regional climate model MIROC5 for 2050 and 2100 were used. The results showed a significant improvement in the system's resilience for light storms and the current period due to LID practice interventions. Efficiencies were reduced for moderate and heavy storms with no significant drops in floodwater depth and resilience regardless of the scenario.

Keywords: historical data source; flood mapping; poorly gauged catchments; citizen science; low impact development

Citation: Fava, M.C.; Macedo, M.B.d.; Buarque, A.C.S.; Saraiva, A.M.; Delbem, A.C.B.; Mendiondo, E.M. Linking Urban Floods to Citizen Science and Low Impact Development in Poorly Gauged Basins under Climate Changes for Dynamic Resilience Evaluation. *Water* **2022**, *14*, 1467. https://doi.org/10.3390/w14091467

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1. Introduction

Historically, cities have been affected by extreme rainfall events and their consequences such as floods and landslides [1–4]. Poor planning and management of the urban space contributes to increasing flood risk for the population due to the housing settlement in steep or floodplain areas and excessive impervious areas and consequently higher runoff generation [5–7]. In developing countries, the housing deficit further increases the occupation of hazardous areas by socially vulnerable populations. Additionally, the pattern of urban occupation and creation of cities has been around rivers due to the need for access to water resources; in many cities, the traditional commercial center is located near floodplain areas [8,9].

Climate change aggravates this risk scenario by increasing the probability of extreme events and their intensities [10–12]. Studies in different regions worldwide show a trend of higher occurrence of storm events, even when there is a decrease in the total rainfall volume

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Article

A Comparison of Continuous and Event-Based Rainfall–Runoff (RR) Modelling Using EPA-SWMM

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Abstract: This study investigates the comparative performance of event-based and continuous simulation modelling of a stormwater management model (EPA-SWMM) in calculating total runoff hydrographs and direct runoff hydrographs. Myponga upstream and Scott Creek catchments in South Australia were selected as the case study catchments and model performance was assessed using a total of 36 streamflow events from the period of 2001 to 2004. Goodness-of-fit of the EPA-SWMM models developed using automatic calibration were assessed using eight goodness-of-fit measures including Nash–Sutcliff efficiency (NSE), NSE of daily high flows (ANSE), Kling–Gupta efficiency (KGE), etc. The results of this study suggest that event-based modelling of EPA-SWMM outperforms the continuous simulation approach in producing both total runoff hydrograph (TRH) and direct runoff hydrograph (DRH).

Keywords: EPA-SWMM; rainfall–runoff modelling; event-based model; continuous simulation

1. Introduction

Rainfall–runoff (RR) models are important tools for planning, design and management of water resource systems. These models are used in a wide range of hydrological applications ranging from the estimation of catchment runoff to analyzing the impact of land-use change on runoff [1]. The methods of synthesizing the rainfall–runoff process in these models differ from one model to another, consequently a variety of model classifications exist. According to Brocca et al. [2], RR models can be classified based on their spatial structure (lumped versus semi-distributed or distributed), time representation (continuous time versus event-based) or process description (physically meaningful versus data-driven). Daniel et al. [3] adopted four different classifications for RR models based on: (i) parameter specification (deterministic or stochastic); (ii) the nature of the basic algorithms (empirical, conceptual or physically-based); (iii) spatial representation (lumped, semi-distributed or distributed); and (iv) the temporal representation (event-based or continuous time). Similar classifications can be found in Elga et al. [4], Singh [5] and Wheater et al. [6]. Of the available models, spatial and temporal representations are the most commonly adopted model types [7,8], while event-based (EB) and continuous simulation (CS) models are the most recognized category within the temporal domain [4,5]. In EB modelling, the rainfall–runoff process in a catchment is simulated for a single rainfall or streamflow event with durations ranging from several hours to several days. Whereas in CS modelling the rainfall–runoff process is simulated for a long time period ranging from a couple of months to several years, including both dry and wet seasons. Generally, in EB modelling, only the infiltration process is modelled in order to account for losses, while in CS modelling, the evapotranspiration loss is also accounted for [9].

CS and EB models both have advantages and limitations. One major advantage of CS modelling is that it is capable of accounting for antecedent conditions such as initial soil-moisture status, stream

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Article

Robust Vegetation Parameterization for Green Roofs in the EPA Stormwater Management Model (SWMM)

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Abstract: In increasingly expanding cities, roofs are still largely unused areas to counteract the negative impacts of urbanization on the water balance and to reduce flooding. To estimate the effect of green roofs as a sustainable low impact development (LID) technique on the building scale, different approaches to predict the runoff are carried out. In hydrological modelling, representing vegetation feedback on evapotranspiration (ET) is still considered challenging. In this research article, the focus is on improving the representation of the coupled soil–vegetation system of green roofs. Relevant data to calibrate and validate model representations were obtained from an existing field campaign comprising several green roof test plots with different characteristics. A coupled model, utilizing both the Penman–Monteith equation to estimate ET and the software EPA stormwater management model (SWMM) to calculate the runoff, was set up. Through the application of an automatic calibration procedure, we demonstrate that this coupled modelling approach (Kling–Gupta efficiency KGE = 0.88) outperforms the standard ET representation in EPA SWMM (KGE = −0.35), whilst providing a consistent and robust parameter set across all green roof configurations. Moreover, through a global sensitivity analysis, the impact of changes in model parameters was quantified in order to aid modelers in simplifying their parameterization of EPA SWMM. Finally, an improved model using the Penman–Monteith equation and various recommendations are presented.

Keywords: green roof; runoff; EPA SWMM; Sedum; Penman–Monteith; parameter optimization

Citation: Iffland, R.; Förster, K.; Westerholt, D.; Pesci, M.H.; Lösken, G. Robust Vegetation Parameterization for Green Roofs in the EPA Stormwater Management Model (SWMM). *Hydrology* **2021**, *8*, 12. https://doi.org/10.3390/hydrology8010012

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1. Introduction

Increasingly expanding cities lead to larger areas of sealed surfaces, offering less space for infiltration and evapotranspiration. This results in increased flooding with stronger peaks, which may be intensified during high rainfall events. Additionally, climate change may contribute to the increase in flood risk [1,2]. In an effort to counteract the negative impacts of urbanization on the water balance and reduce flooding through retention, roofs are still underutilized areas. Various concepts focusing on more sustainable approaches to improve urban stormwater management are currently under development, such as low impact development (LID) technologies, which are ecologically based approaches that combine urban and natural systems [3].

Green roofs, as a sustainable LID technique on the building scale, are becoming an alternative to impermeable roofs and aim to integrate the built infrastructure into the landscape [4]. They basically consist of a substrate layer of growing medium covered by vegetation, a drainage system and a waterproof membrane with root penetration resistance [1,5]. Green roofs are often classified into extensive or intensive, depending on the thickness of the substrate layer. Extensive green roofs have a maximum substrate layer thickness of approx. 150 mm and are usually covered by drought resistant plants (i.e., *Sedum*), whereas intensive green roofs can present a greater thickness and are often covered by perennial plants (i.e., shrubs and trees) [1,6].

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Article

Modeling the Hydraulic Performance of Pilot Green Roofs Using the Storm Water Management Model: How Important Is Calibration?

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Abstract: Green roofs are low-impact development (LID) that assist in regulating stormwater runoff by reducing the peak flow rate and total runoff volume, among other benefits. In this study, the hydraulic performance of green roofs was modeled using the SWMM 5.2 software, taking field data into account for calibration purposes. A Storm Water Management Model (SWMM) was built using field data from pilot green roofs installed at the Instituto Superior Técnico Campus, University of Lisbon, Portugal. The simulated results with and without calibration were compared, as well as the results obtained in the field studies. The results from the uncalibrated model were unsatisfactory. After calibration, the average Nash–Sutcliffe model efficiency (NSE) was 0.72, and the volume error was 5.9%, with most of the results classified as very good and good. This study shows relevant insights on the use of the SWMM to model green roofs, demonstrating the crucial importance of the calibration process for the correct prediction of hydraulic performance and indicating the porosity parameter as one of the most sensitive to the results. In addition, it provides estimates of LID parameters that can help in the development of projects carried out in the Mediterranean climate.

Keywords: calibration; green roofs; modeling; Storm Water Management Model (SWMM)

Citation: Weggemans, J.; Santos, M.L.; Ferreira, F.; Moreno, G.D.; Matos, J.S. Modeling the Hydraulic Performance of Pilot Green Roofs Using the Storm Water Management Model: How Important Is Calibration? *Sustainability* **2023**, *15*, 14421. https://doi.org/10.3390/su151914421

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1. Introduction

1.1. Background

In a context of growing urbanization and increasing impervious areas, stormwater management represents a major challenge for cities [1]. The implementation of urban green infrastructure, in parallel with existing gray infrastructure, is a way to benefit urban areas, namely with the reduction in urban surface runoff. These green solutions, also called low-impact development (LID), are source control measures, which are considered an effective strategy in stormwater management [2,3].

Green roofs are one of the LID measures, and they have become increasingly popular as they assist in regulating stormwater runoff by reducing the peak flow rate and total runoff volume [4–7].

In order to effectively design and manage green roofs for stormwater management purposes, it is important to understand how different factors influence their hydrological performance. Several studies have focused on understanding the impact of different factors on green roof performance, such as substrate characteristics and composition [8–10]; roof geometry [4,11]; and natural factors, such as weather conditions and precipitation patterns [12,13]. The large number of factors affecting the performance of green roofs explains the high variability of retention results that are reported in studies [14]. Retention is defined by the difference between the total depth of precipitation and the total depth of runoff, divided by the total depth of precipitation [1]. When comparing the results of three different studies on green roofs, the retention performances ranged between 10% and

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Article

Evaluating Curve Number Implementation Alternatives for Peak Flow Predictions in Urbanized Watersheds Using SWMM

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Abstract: The application of hydrologic modeling tools to represent urban watersheds is widespread, and calculation of infiltration losses is an essential component of these models. The curve number (CN) method is widely used in such models and is implemented in US EPA's Storm Water Management Model (SWMM 5). SWMM 5 models can be created either using CN values computed only for the pervious fraction of subcatchments, or using the entire subcatchment area, but choice is not clearly understood. The present work evaluates the differences between these approaches in CN computation within SWMM through a comparison with field data collected in an urban watershed in Alabama and with WinTR-55. Four approaches to computing CN were considered in which the impervious fractions varied according to a threshold CN value. Results indicated that a Fully Composite approach, which computed CN from all subcatchment areas, yielded the best results for the sub-watershed with higher average CN. It was also observed that results from the approaches using CN Cut-off values of 90 and 93 were better for subcatchments with lower average CN. The comparison between SWMM 5 and WinTR-55 indicated that SWMM 5 hydrographs had larger peak flow rates, but these differences decreased with larger intensity rain events. Research findings are useful to hydrologic modelers, and in particular for setting up SWMM 5 models using CN method.

Keywords: hydrologic models; curve number; SWMM; WinTR-55

Citation: Xiao, H.; Vasconcelos, J.G. Evaluating Curve Number Implementation Alternatives for Peak Flow Predictions in Urbanized Watersheds Using SWMM. *Water* **2023**, *15*, 41. https://doi.org/10.3390/w15010041

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1. Introduction and Objectives

Hydrologic models are used to simulate the natural process related to water movement and are important instruments for urban stormwater management. Such models can provide important insights into various water resource problems for engineers and designers, including predicting peak flow depth in urban streams. The prediction of peak flow depth is one of the most relevant problems in urban watersheds, as these flows can lead to disasters such as flash flooding. Hydrologic models that can be applied for peak flow predictions in urban areas include the Hydrologic Modeling System (HEC-HMS) developed by the U.S. Army Corps of Engineers [1]; the Storm Water Management Model (SWMM 5) developed by the U.S. Environmental Protection Agency [2]; and the WinTR-55 Small Watershed Hydrology (WinTR-55) developed by U.S. Department of Agriculture [3]. One of the most popular models in urban hydrological applications is SWMM 5, originally designed to support urban stormwater management.

An important mechanism for hydrological abstraction is infiltration, defined as the process by which precipitation penetrates the soil [4]. Infiltration is a complex data input in hydrologic models and plays a key role in runoff calculations. Hydrologic models such as SWMM have various methodologies to compute infiltration, including Horton [5], Green-Ampt [6], and curve number (CN) [7] methods. The CN method has the least parameters compared to other alternatives for infiltration estimates in SWMM 5. CN values depend on soils' characteristics and types of land use. Soils with high infiltration rates and undeveloped land use types have low CN coefficient values and lower potential for

water

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Article

An Event-Based Stochastic Parametric Rainfall Simulator (ESPRS) for Urban Stormwater Simulation and Performance in a Sponge City

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Abstract: The temporal heterogeneity of rainfall is substantial in urban catchments, and it often has huge impacts on stormwater simulation and management. Using a design storm with a fixed pattern may cause uncertainties in hydrological modeling. Here, we propose an event-based stochastic parametric rainfall simulator (ESPRS) for stormwater simulation in a sponge city with green roofs, permeable pavements, and bioretention cells. In the ESPRS, we used five distributions to fit the measured rainfall events and evaluated their performance using Akaike's Information Criterion, Anderson—Darling goodness-of-fit test, and *p*-values. The vast rainfall time series data generated using the ESPRS were used to run the storm water management model for outflow simulations in the catchment, thus revealing the influence of temporal rainfall characteristics on the hydrological responses. The results showed the following: (1) The ESPRS outperforms the Chicago method in predicting extreme precipitation events, and its control factors are the rainfall peak period, rainfall peak fraction, and cumulative rainfall fraction at the peak period. (2) The best-fit functions for the rainfall depth in each period have different distributions, mostly being in lognormal, gamma, and generalized extreme value distributions. (3) Rear-type precipitation events with high peak fractions are the most negative pattern for outflow control. The developed ESPRS can suitably reproduce rainfall time series for urban stormwater management.

Keywords: low-impact development; MATLAB; outflow; rainfall pattern; storm water management model (SWMM)

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Citation: Yang, Y.; Xu, X.; Liu, D. An Event-Based Stochastic Parametric Rainfall Simulator (ESPRS) for Urban Stormwater Simulation and Performance in a Sponge City. *Water* **2023**, *15*, 1561. https://doi.org/10.3390/w15081561

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1. Introduction

China has constructed sponge cities based on low-impact development practices (LIDs) and super drainage systems to control short, intense rainfall events [1]. However, most urban areas lack measured rainfall and runoff data with high spatial and temporal resolutions. Meanwhile, performing rainfall assimilation on multiple sources [2], such as meteorological satellite retrieval, radar, and microwave measurements, has significant uncertainties at a small catchment scale. The lack of observed data leads to a weak understanding of the influence of the temporal and spatial structures of rainfall on urban runoff processes.

The spatial variation and structures of rainfall, such as the coverage, center, and movement paths, significantly impact floods [3,4]. The spatial movement and transposition of rainfall [5,6] have been extensively investigated in large basins, and so have the spatial resolution [7–10], spatial decomposition, and the influence of spatial heterogeneity on hydrological processes [11,12]. Rainfall models can be classified according to whether and how the method describes the spatial correlation—single-point, multi-point [13,14], and field [15,16].

Rainfall temporal structures, such as the precipitation, duration, and pattern, play an essential role in urban stormwater simulation and control. For a storm with a short return period, the precipitation and peak intensities have a more significant effect on the

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Article

Coupling a Distributed Time Variant Gain Model into a Storm Water Management Model to Simulate Runoffs in a Sponge City

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Abstract: The storm water management model (SWMM) has been used extensively to plan, implement, control, and evaluate low impact development facilities and other drainage systems to solve storm-related problems in sponge cities. However, the calibration of SWMM involves a variety of sensitive parameters and may bring significant uncertainties. Here we incorporated the distributed time variant gain model (DTVGM), a model with a simple structure and few parameters, into the SWMM (called DTVGM-SWMM) to reduce the complexity but keep the mechanistic representation of the hydrological process. The DTVGM runoff module parameters were calibrated and validated using the Nash–Sutcliffe efficiency (NSE), based on measured data and the results of SWMM. It was then coupled with the SWMM routing module to estimate catchment runoffs and outflows. Finally, the performance was evaluated using NSE (0.57~0.94), relative errors of the flow depth (−7.59~19.79%), and peak flow rate (−33.68~54.37%) under different storm events. These implied that the DTVGM-SWMM simulations were generally consistent with those of the control group, but underperformed in simulating peak flows. Overall, the proposed framework could reasonably estimate the runoff, especially the outflow process in the urban catchment. This study provides a simple and reliable method for urban stormwater simulation.

Keywords: SWMM; TVGM; sponge city; low impact development

Citation: Yang, Y.; Zhang, W.; Liu, Z.; Liu, D.; Huang, Q.; Xia, J. Coupling a Distributed Time Variant Gain Model into a Storm Water Management Model to Simulate Runoffs in a Sponge City. *Sustainability* **2023**, *15*, 3804. https://doi.org/10.3390/su15043804

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1. Introduction

Rapid urbanization has caused various problems in constructed areas [1]. Increased surface runoff, frequent flooding, and water deterioration have significantly impacted the environment and the economy [2,3]. In the last decade, the Chinese government has launched sponge city construction [4], which often uses low impact development facilities (LIDs) as source control measurements [5]. A sponge city is a city with low impact development infrastructure, which aims to make the catchment hydrological response approach the pre-development status with minimum cost. In sponge cities, the runoff response to rainfall has significant nonlinear characteristics, which can be depicted by the storm water management model (SWMM), widely used in urban hydrology [6–8]. However, SWMM requires many parameters and much measured data; moreover, it operates in a complicated way.

On the other hand, the distributed time variant gain model (DTVGM) has few parameters and a simple structure for representing the rainfall-runoff response [9,10]. It can simulate complex nonlinear hydrological processes, but is generally used in large natural watersheds with low-intensity human activities under prolonged rainfalls. Thus far, DTVGM has rarely been used to simulate the rainfall runoff process in sponge cities as urban areas always have small areas, complicated land use and land cover, and, in most cases, short and intense storms. It would be questionable to apply it to a study subject

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B.6. TETIS

CG9. B6

1. Descripción

El modelo TETIS ha sido desarrollado para realizar la simulación hidrológica en cuencas naturales, aunque dispone de submódulos para la simulación del efecto de embalses y del riego agrícola. El objetivo de este software es obtener de la mejor forma posible la respuesta hidrológica ocasionada por la precipitación de lluvia o de nieve, teniendo en cuenta los diferentes procesos físicos involucrados y empleando la modelación distribuida de tipo conceptual.

Este programa incluye una amplia variedad de métodos para realizar interpolaciones además de contar con modelos de producción de la escorrentía, fusión de nieve, laminación de embalses y traslación a lo largo de los cauces. Todo con el objeto final de justificar el uso de la modelación distribuida conceptual para la simulación hidrológica.

Este programa es desarrollado y mantenido por el Grupo de Investigación de Modelación Hidrológica y Ambiental (GIMHA) que forma parte del Área de Investigación de Hidráulica e Hidrología del Instituto de Ingeniería del Agua y el Medio Ambiente (IIAMA), dentro de la Universidad Politécnica de Valencia.

En sus más de 20 años de historia, el modelo ha sido ampliamente utilizado en España y otros países del mundo. TETIS se ha implementado en cuencas de todo tamaño, desde menores a 1 km^2 hasta los 98.500 km^2 del río Ródano en Francia. Cabría destacar en estos momentos que el modelo TETIS se encuentra operativo como modelo de predicción de crecidas en el SAIH de la Agencia Vasca del Agua, y al mismo tiempo sirvió de base para la estimación de recursos hídricos de la Comunidad Autónoma del País Vasco.

Las principales investigaciones en las que se ha usado TETIS recientemente son Beneyto et al., 2020; Casado-Rodríguez y del Jesus, 2022; Echeverría et al., 2019; Gomis-Cebolla et al., 2022;

Pineda Capacho et al., 2022 y Salgado-Castillo et al., 2023.

2. Características técnicas

Programa	TETIS		
Versión	9	Año	2023
Tipología	Modelación hidrológica		
Capacidades del programa	Modelo de simulación hidrológica y del ciclo de sedimentos de tipo distribuido en el espacio mediante una subdivisión de la cuenca en celdas regulares, con parámetros físicamente basados. Es un modelo global, es decir, con un mismo modelo se pueden resolver problemas tanto de Crecidas y Erosión (discretización temporal de minutos u horas) como de Recursos Hídricos (discretización temporal diaria). Además, tiene un potente algoritmo de calibración automática de sus parámetros efectivos y de los valores iniciales de todas las variables de estado, que facilita enormemente su implementación práctica.		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
Tipo de sistema (arquitectura)	32 y 64 bits	Tipo de licencia	Código Abierto (previo registro) licenciado bajo GNU (General Public License)
Desarrollador	Grupo de Investigación de Modelación Hidrológica y Ambiental (GIMHA)		
Web	https://www.iiama.upv.es/iiama/es/transferencia/software/tetis-e.html		

3. Ejemplos de trabajos científicos

water

MDPI

Article

New Approach to Estimate Extreme Flooding Using Continuous Synthetic Simulation Supported by Regional Precipitation and Non-Systematic Flood Data

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check for updates

Abstract: Stochastic weather generators combined with hydrological models have been proposed for continuous synthetic simulation to estimate return periods of extreme floods. Yet, this approach relies upon the length and spatial distribution of the precipitation input data series, which often are scarce, especially in arid and semiarid regions. In this work, we present a new approach for the estimation of extreme floods based on the continuous synthetic simulation method supported with inputs of (a) a regional study of extreme precipitation to improve the calibration of the weather generator (GWEX), and (b) non-systematic flood information (i.e., historical information and/or palaeoflood records) for the validation of the generated discharges with a fully distributed hydrological model (TETIS). The results showed that this complementary information of extremes allowed for a more accurate implementation of both the weather generator and the hydrological model. This, in turn, improved the flood quantile estimates, especially for those associated with return periods higher than 50 years but also for higher quantiles (up to approximately 500 years). Therefore, it has been proved that continuous synthetic simulation studies focused on the estimation of extreme floods should incorporate a generalized representation of regional extreme rainfall and/or non-systematic flood data, particularly in regions with scarce hydrometeorological records.

Keywords: weather generator; palaeoflood; regional extreme precipitation study; ephemeral river; fully distributed hydrology; flood quantiles; Rambla de la Viuda

1. Introduction

Accurate estimates of extreme and rare floods have been a fundamental problem in flood hydrology since pioneer work by Foster [1], and it is still present among the scientific and engineering communities in numerous papers and reports. Stedinger and Griffis [2] evaluate critical issues on flood frequency methods, recommending practical developments, among others, on: (i) extending flood records with historical and non-standard flood data (e.g., palaeofloods), which can be called non-systematic information [3]; (ii) generation of flood data from rainfall records using conceptually based and spatially fully distributed watershed models; and (iii) advances in setting realistic physical limits on precipitation and flows in a given catchment. These research topics seek to gain knowledge about the tail of the frequency distribution describing the extremes, particularly in data-poor regions, either by using regional flood methods [4], extending the flood registers [5], and improving parameter estimates related to the distribution shape with upper bounds (e.g., [6]) or identifying low outliers in flood

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Research papers

Hydrograph separation for tackling equifinality in conceptual hydrological models

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ARTICLE INFO

This manuscript was handled by Marco Borga, Editor-in-Chief, with the assistance of Stefano Orlandini, Associate Editor

Keywords:
Hydrological modeling
Calibration
Equifinality
Hydrograph separation

ABSTRACT

Attributing a physical meaning to the calibration of a conceptual hydrological model is a risk due to equifinality, i.e., the existence of multiple optimal parameterizations that might or might not represent the actual behavior of a catchment; a risk that propagates to posterior studies that use the outputs of the hydrological model as an input. This study proposes and analyses sequential procedures for calibrating conceptual hydrological models aimed at reducing equifinality. These procedures force the model to reproduce a flow separation of the observed streamflow into quick flow and base flow, which we assumed representative of the run-off generating processes in the catchment. The sequential calibration of the model parameters that control quick flow and base flow forces the model to reproduce the flow separation, and introduces additional constraints in the calibration process that reduce equifinality and improve the overall calibration procedure. We applied this procedure to two mesoscale catchments in the "Picos de Europa" National Park (northern Spain). We compared the performance of the different calibration procedures both in the real scenario and in hypothetical scenarios of land use and soil permeability, to provide a sounder assessment of the ability of the procedures under diverse conditions. Results show that a calibration method applying hydrograph separation ensures models with a better discharge partition, whereas methods that do not apply separation failed in a considerable number of cases. In terms of performance (NSE and bias), the method applying hydrograph separation outperformed the reference method (without separation) for the real scenario, even for total streamflow; in the hypothetical scenarios though, the improvement in process representativeness came at the expense of a slight loss in performance. The sequential methods here developed were more computationally efficient; since they explore the parameter space in subsets, the number of iterations until convergence was a third of that needed with the reference method. In summary, we have developed a simple calibration procedure that ensures a better model behavior (more in line with the underlying conceptualization) with a similar, and even better, performance and a shorter calibration time than the reference method.

1. Introduction

Reproducing the real functioning of a catchment by calibration of a conceptual hydrological model is an extremely complicated task due to the multidimensionality of the optimisation problem (Shokri et al., 2018). The equifinality of a model is the impossibility to select a single best model parameterization from the set of parameterizations with optimal performance (Beven and Freer, 2001). These multiple optimal parameterizations might represent models that behave in distinct ways, i.e., in which the processes generating discharge (overland flow, interflow and base flow) are differently partitioned (Beven and Binely, 1992). The usual calibration procedure, either using manual or automatic calibration, would choose the model parameterization that maximizes a specific performance metric. However, the parameter set with the highest performance might not reproduce the actual catchment functioning; instead, sub-optimal parameterizations might be more realistic (Kavetski, 2018).

Equifinality is partly caused by the large number of parameters present in conceptual hydrological models (even though physical processes-based models may contain even more parameters) and the lack of observations against which to compare the model outputs (Shokri et al., 2018), which in a regular case in hydrology is the observed discharge in one (or several) gauging station. It may even be exacerbated -in conceptual models- due to the limited physical base of some of the

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water

MDPI

Article

Assessment of Remotely Sensed Near-Surface Soil Moisture for Distributed Eco-Hydrological Model Implementation

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Abstract: The aim of this study was to implement an eco-hydrological distributed model using only remotely sensed information (soil moisture and leaf area index) during the calibration phase. Four soil moisture-based metrics were assessed, and the best alternative was chosen, which was a metric based on the similarity between the principal components that explained at least 95% of the soil moisture variation and the Nash-Sutcliffe Efficiency (NSE) index between simulated and observed surface soil moisture. The selected alternative was compared with a streamflow-based calibration approach. The results showed that the streamflow-based calibration approach, even presenting satisfactory results in the calibration period (NSE = 0.91), performed poorly in the validation period (NSE = 0.47) and Leaf Area Index (LAI) and soil moisture were neither sensitive to the spatio-temporal pattern nor to the spatial correlation in both calibration and validation periods. Hence, the selected soil moisture-based approach showed an acceptable performance in terms of discharges, presenting a negligible decrease in the validation period (ΔNSE = 0.1) and greater sensitivity to the spatio-temporal variables' spatial representation.

Keywords: eco-hydrological modelling; remotely sensed soil moisture; objective-function; spatial correlation

1. Introduction

The traditional approach to hydrological model calibration is based only on observed streamflow time series at available gauging stations within the studied basins. However, the assessment of streamflow for a river basin provides an aggregated signal and provided a limited information on the behavior of other relevant state variables of the system [1–7]. In order to deal with this, the data obtained from remote sensing satellites has become a key alternative [8–17], significantly increasing the use of this type of information in recent decades for state variables used in ecohydrology [18]. In fact, remote sensing data not only provides temporal information, but also valuable information on spatial dynamics, which can facilitate model calibration considering spatial patterns and the temporal dynamics.

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Research papers

Evaluation of Sentinel-1, SMAP and SMOS surface soil moisture products for distributed eco-hydrological modelling in Mediterranean forest basins

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ARTICLE INFO

Keywords:
Surface soil moisture
Remote sensing
Spatial patterns
Eco-hydrological modelling
Multi-variable calibration

ABSTRACT

Reliable distributed hydrological modeling, especially in semi-arid areas, must consider the inclusion of surface soil moisture (SSM) spatial information during the calibration process. This variable plays a key role in the evapotranspiration processes that determine the hydrological cycle. The coarse resolution of the SSM estimates by satellite remote sensing has restricted the application of this approach to only large basins, focusing most of the studies in the consideration of simply the temporal dynamics of this variable. The growing efforts in providing higher spatial resolution through disaggregating methodologies or new sensor estimates facilitates the application of this spatial approach to small basins. This paper explores the applicability of the currently available satellite surface soil moisture estimates for distributed eco-hydrological modelling in Mediterranean forest basins. On one hand, this study contributes to fill the existing research gap on the use of remote sensing SSM spatial patterns within the distributed hydrological modelling framework in small basins. On the other hand, it serves as an indirect validation method for the spatial performance of satellite SSM products. To achieve this goal, we implemented the eco-hydrological model TETIS in three case studies named: Hozgarganta (southern Spain), Ceira (western Portugal) and Carraixet (eastern Spain). The SSM estimates selected for comparison were Sentinel-1 SSM provided by the Copernicus Global Land Services (CGLS), SMAP SSM disaggregated using Sentinel-1 (SPL2SMAP_S) provided by the National Aeronautics and Space Administration (NASA), SMOS SSM provided by the Barcelona Expert Center (BEC), and SMOS and SMAP SSM disaggregated using the DISPATCH algorithm provided by Lobelia Earth. The methodology employed involved a multi-objective and multi-variable calibration in terms of remote sensing SSM spatial patterns and in-situ streamflow, using the Spatial Efficiency Metric (SPAEF) and the Nash-Sutcliffe efficiency index (NSE) respectively. Before model calibration a sensitivity analysis of the most influent variables was performed. The temporal and spatial comparison of the reference SSM products revealed inconsistencies amongst products. The disaggregating methodology determined the spatial agreement to a greater degree than the sensor itself (i.e. SMAP, SMOS). In spite of the differences amongst products, the multi-objective calibration approach proposed increased the robustness of the hydrological modelling.

1. Introduction

The reliable determination of the hydrological variables in a catchment has been a challenging objective for a long time. Many hydrological models have emerged as a response to growing demand of operational tools. Amongst them, deterministic distributed hydrological models offering spatial explicit predictions can fulfil the lack of spatial representation of the dominant hydrological processes when available in-situ observations are not sufficient. Traditionally, hydrological model calibration was based on solely streamflow information. However, this does not guarantee the correct representation of the spatial heterogeneity of other state variables (Rajib et al., 2016; Wambura et al., 2018). The introduction in hydrological models of satellite derived information has the potential to overcome this limitation by improving models performance, both temporally and spatially (Laiolo et al., 2016; Lopez et al., 2017; Herman et al., 2018; Dembelé et al., 2020a). Additionally, it should not be ignored the existing relationship between vegetation dynamics and the related hydrological processes. Thus, vegetation requires proper representation in eco-hydrological models to attend reliability requirements in catchments with representative areas of forestry or

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Evaluación del impacto de la urbanización y el cambio climático sobre la recarga de aguas subterráneas y el balance hidrológico en la subcuenca del río Turbio, Guanajuato

Assessment of the impact of urbanization and climate change on groundwater recharge and hydrological balance in the Turbio river watershed, Guanajuato

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Resumen

Evaluar los potenciales impactos del cambio climático y las urbanizaciones en un sistema hidrológico resulta de gran importancia al momento de elaborar estrategias de mitigación y adaptación para garantizar agua a todos los sectores de la población. Es por ello, que en esta investigación se evalúa, mediante proyecciones y un modelo hidrológico distribuido, los efectos de una de las zonas urbanas más importantes del estado de Guanajuato sobre los procesos del ciclo hidrológico, específicamente en la recarga de los acuíferos y las implicaciones futuras que tendrá el cambio climático en las grandes ciudades. Los resultados obtenidos muestran que la precipitación disminuirá y el almacenamiento en el suelo se verá reducido principalmente en las zonas urbanas. Se producirá menor infiltración y percolación en el sistema. En condiciones de cambio climático se pronostica una disminución en la recarga de los acuíferos de hasta un 24.9% para el año 2035.

Palabras clave: Cambio climático; ciclo hidrológico; aguas subterráneas; modelo TETIS.

Abstract

Assessing the potential impacts of climate change and urbanization in a hydrological system is of great importance when developing mitigation and adaptation strategies that ensure water for all sectors of the population. For this reason, this research evaluates, through projections and a distributed hydrological model, the effects of one of the most important urban areas in the state of Guanajuato on the processes of the hydrological cycle, specifically on the recharge of aquifers and the future impacts of climate change in large cities. The results show that precipitation will decrease, and with it, soil storage will be reduced mainly in urban areas. Moreover, there will be less infiltration and percolation in the system. A decrease in aquifer recharge of up to 24.9% is also forecast for the year 2035.

Keywords: Climate change; hydrological cycle; groundwater; TETIS model.

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Skew-normal distribution model for rainfall uncertainty estimation in a distributed hydrological model

Félix Salgado-Castillo, Miguel Barrios & Jorge Velez Upegui

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Casado-Rodríguez, J. y del Jesus, M. (2022). Hydrograph separation for tackling equifinality in conceptual hydrological models. Journal of Hydrology, 610, 127816. https://doi.org/10.1016/j.jhydrol.2022.127816

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Gomis-Cebolla, J., Garcia-Arias, A., Perpinyà-Vallès, M. y Francés, F. (2022). Evaluation of Sentinel-1, SMAP and SMOS surface soil moisture products for distributed eco-hydrological modelling in Mediterranean forest basins. Journal of Hydrology, 608, 127569. https://doi.org/10.1016/j.jhydrol.2022.127569

Pineda Capacho, P. A., Martínez Bárcemas, A., Aguilera Rico, H. A., y Orozco Medina, I. (2022). Evaluación del impacto de la urbanización y el cambio climático sobre la recarga de aguas subterráneas y el balance hidrológico en la subcuenca del río Turbio, Guanajuato. Acta Universitaria, 32, 1–14. https://doi.org/10.15174/au.2022.3485

Salgado-Castillo, F., Barrios, M. y Velez Upegui, J. (2023). Skew-normal distribution model for rainfall uncertainty estimation in a distributed hydrological model. Hydrological Sciences Journal, 68 (4), 542-551. https://doi.org/10.1080/02626667.2023.2185149

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B.7. SWAT+

CG9. B7

1. Descripción

SWAT, Soil & Water Assessment Tool (Herramienta de Evaluación de Suelos y Aguas) es un modelo a escala de cuenca pequeña a cuenca fluvial que se utiliza para simular la calidad y cantidad de agua superficial y subterránea, así como, predecir el impacto ambiental del uso del suelo, las prácticas de gestión de la tierra y el cambio climático. SWAT se utiliza ampliamente para evaluar la prevención y el control de la erosión del suelo, el control de la contaminación de fuentes difusas y la gestión regional de cuencas hidrográficas.

Diversas aplicaciones del modelo han revelado limitaciones e identificado necesidades de desarrollo del modelo. Numerosas adiciones y modificaciones del modelo y sus componentes individuales han hecho que el código sea cada vez más difícil de gestionar y mantener. En respuesta a estos problemas y para afrontar los desafíos presentes y futuros en la modelización de recursos hídricos, tras importantes modificaciones del código en los últimos años, dando como resultado SWAT+.

SWAT+ es una versión completamente reestructurada del modelo. Manteniendo los algoritmos básicos utilizados para calcular los procesos en el modelo, se ha modificado significativamente la estructura y organización tanto del código (basado en objetos) como de los archivos de entrada (basados en relaciones). Se espera que esto facilite el mantenimiento del modelo, modificaciones futuras del código y fomente la colaboración con otros investigadores para integrar nueva ciencia en los módulos SWAT. Además, SWAT+ ofrece una representación espacial más flexible de las interacciones y procesos dentro de una cuenca.

Las principales investigaciones en las que se ha usado SWAT+ recientemente son Alawi y Özkul, 2023; Chen et al., 2023; Germeç y Ürker, 2023; Islam et al., 2023; Salim Aoubid y Opp, 2023;

Satriagasa et al., 2023; Verma et al., 2023 y Vogeti et al., 2023.

2. Características técnicas

Programa	SWAT+		
Versión	2.3.7	Año	2023
Tipología	Modelación hidrológica		
Capacidades del programa	La Herramienta de Evaluación de Suelos y Aguas (SWAT) es un modelo a escala de cuenca pequeña a fluvial que se utiliza para simular la calidad y cantidad de agua superficial y subterránea y predecir el impacto ambiental del uso de la tierra, las prácticas de gestión de la tierra y el cambio climático. SWAT se utiliza ampliamente para evaluar la prevención y el control de la erosión del suelo, el control de la contaminación de fuentes difusas y la gestión regional en cuencas hidrográficas.		
Sistema operativo	Linux (64 bits), 2.3.1		
	Windows (64 bits)		
	macOSX (64 bits y arm M1 y M2), 2.3.1		
Tipo de sistema (arquitectura)	64 bits arm M1 y M2	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, part of The Texas A&M University System		
Web	https://swat.tamu.edu/		

3. Ejemplos de trabajos científicos

H2Open Journal

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H2Open Journal Vol 6 No 1, 63 doi: 10.2166/h2oj.2023.062

Evaluation of land use/land cover datasets in hydrological modelling using the SWAT model

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ABSTRACT

Land use/land cover (LULC) is a key influencer for runoff generation and the estimation of evapotranspiration in the hydrology of watersheds. Therefore, it is essential to use accurate and reliable LULC data in hydrological modelling. Ground-based data deficiencies are a big challenge in most parts of developing countries and remote areas around the globe. The main objective of this research was to evaluate the accuracy of LULC data from two different sources in hydrological modelling using the soil and water assessment tool (SWAT). The first LULC data was prepared by the classification of Landsat 8 satellite imagery, and the second LULC data was extracted from the ESRI 2020 global LULC dataset. The study was conducted on the Kokcha Watershed, a mountainous basin partly covered by permanent snow and glaciers. The accuracy assessment was done based on a comparison between observed river discharge and simulated river flow, utilizing each LULC dataset separately. After calibration and validation of the models, the acquired result was approximately similar and slightly (5.5%) different. However, due to the higher resolution and easily accessible ESRI 2020 dataset, it is recommended to use ESRI 2020 in hydrological modelling using the SWAT model.

Key words: Amu Darya, hydrological modelling, Kokcha Watershed, LULC datasets, SWAT model

HIGHLIGHTS

- Two land use/land cover (LULC) datasets were evaluated to analyse their accuracy.
- The ESRI LULC dataset represents a more accurate result than LULC data, which was prepared by the classification of Landsat 8 satellite images.
- The utilized remote sensing data in this study can be used in hydrological modelling for similar studies in the region.

climate

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Article

Application of Hydrological Modeling Related to the 2011 Disaster in the Mountainous Region of Rio De Janeiro, Brazil

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Abstract: Natural disasters have been responsible for thousands of deaths in recent decades that, added to the environmental, social and economic impacts, require the implementation of prevention strategies. The largest share of disasters is of hydrological origin. In this context, hydrological models are potential alternatives for monitoring and preventing events of this nature. The objective of this study was to analyze the applicability of the semi-distributed model SWAT (Soil and Water Assessment Tool) and the concentrated model SMAP (soil moisture accounting procedure) in predicting the extreme flood event that occurred in Brazil in the mountainous region of Rio de Janeiro in 2011. The results showed that the mean relative error in calibration and validation was 12% and 53% for SMAP, and 18.46% and 88.73% for SWAT, respectively. The better performance of SMAP in validation integrated with its ease of data collection, simplicity of execution and semi-automatic calibration included in its routine, allows for the conclusion that this model proved to be more suitable for hydrological monitoring. In this study, for the first time, a model of SWAT's complexity was applied to a watershed located in the mountainous region of the state of Rio de Janeiro, a region that, unfortunately, has accounted for thousands of deaths over the past decades associated with mass movements and floods. The SWAT model, besides being able to predict the level and flow of the main course of the river and its tributaries, also enables the calculation of sediment transport in extreme events. Looking from an operational point of view, the work clearly shows how poor hydro-meteorological monitoring, as is the case in this region, makes a good quality prediction for extreme events impossible. It was demonstrated that under these conditions, a simpler and concentrated modeling approach, such as the SMAP model, is able to obtain better results than SWAT.

Keywords: natural disasters; hydrological models; environmental monitoring

Citation: Chen, M.; Cataldi, M.; Francisco, C.N. Application of Hydrological Modeling Related to the 2011 Disaster in the Mountainous Region of Rio De Janeiro, Brazil. *Climate* **2023**, *11*, 55. https://doi.org/10.3390/cli11030055

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1. Introduction

Natural disasters have been highlighted by the severity of the impacts generated in society, the environment and the countless lives lost where they occur. The disasters were responsible for 3.3 million deaths in 40 years of records [1] These events affected an annual average of 193.4 million people for the period between 2001 and 2021. Events of hydrological origin (floods and landslides) configure the largest share of disasters affecting the world population [2]. In Brazil, drought is the event of highest incidence, followed, respectively, by torrents and floods [3].

The natural disaster that occurred in 2011 in the mountainous region of Rio de Janeiro, Brazil, was the worst event in the country. As a result, new instruments and guidelines were created to deal with natural disasters established by Law No. 12608/2012 [4]. However, despite this progress, disasters continue to impact countless lives in this same region, where fatalities were recorded again due to heavy rains in 2022.

The need to reduce the impacts of disasters, whose incidence has become more recurrent, leads to the search for the reduction of vulnerability and exposure of the system to risks, not only with the adoption of structural but also non-structural measures, aimed at increasing the perception of and resilience to these events [5,6].

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Article

Investigation of a SWAT Model for Environmental Health Management Based on the Water Quality Parameters of a Stream System in Central Anatolia (Türkiye)

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Abstract: Water is one of the most critical factors affecting environmental health. Therefore, it is essential to be able to predict water behavior in nature and prevent water pollution to avoid environmental health problems. In order to predict the behavior of water, the hydrological cycle needs to be evaluated at the basin level. To this aim, hydrological models can be used to obtain mathematical representations of hydrological processes. These models allow the anticipation and monitoring of issues regarding water quality, pollution, sediment transport, and proliferation of oil, and petroleum derivatives, among others, which can affect environmental health. In this study, a 2D surface water model was created using the soil and water assessment tool (SWAT) to simulate the lotic ecosystem and present water quality in the Tatlıçay Basin and to propose solutions for improving environmental health in the Cankiri provincial center in Türkiye. The accuracy of the input data and the validity of the model were tested with calibration and validation studies by using monthly or trimonthly observation data obtained from the flow observation and water quality stations of the General Directorate of State Hydraulic Works from 2016 to 2020. The aim was to create a model able to provide fast, accurate, and practical solutions in the face of water-related and environmental issues. The calibration and validation of this model were successfully carried out with very few observation data. Since surface water models are dynamic, long-term daily or monthly flow and water quality measurements should increase the accuracy of their predictions. Additionally, in the presence of pollution sources that may affect environmental health, monitoring and analyses of their possible effects should be carried out. As one of the few studies from the Middle East describing a hydrological model, this research makes a significant contribution to the literature on environmental health.

Keywords: environmental health; eco-hydrology; hydrologic model; water quality; soil and water assessment tool (SWAT)

Citation: Germeç, E.; Ürker, O. Investigation of a SWAT Model for Environmental Health Management Based on the Water Quality Parameters of a Stream System in Central Anatolia (Türkiye). *Sustainability* **2023**, *15*, 13850. https://doi.org/10.3390/su151813850

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1. Introduction

River ecosystems represent one of the most well-known and important sources of clean water, with unrivalled importance for the biosphere [1]. Like all other clean water sources, rivers are under threat from natural and anthropogenic pressures [2]. Therefore, it is important to define these pressures and identify their pollutant burden [3]. Hydrological models are among the most accurate tools to analyze water resources. Hydrological models can be applied at basin scale, are cost- and time-efficient, can use already available data, and can be employed for areas where parameter measurement is difficult [4]. When using hydrological models, precautions can be taken to protect urban and environmental health, and possible unexpected problems can be easily overcome [5,6].

Hydrological modelling involves tools that allow the opportunity to solve equations representing real surface water systems, suitably simplified [7]. At the same time, since

remote sensing

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Article

Exploring Random Forest Machine Learning and Remote Sensing Data for Streamflow Prediction: An Alternative Approach to a Process-Based Hydrologic Modeling in a Snowmelt-Driven Watershed

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Abstract: Physically based hydrologic models require significant effort and extensive information for development, calibration, and validation. The study explored the use of the random forest regression (RFR), a supervised machine learning (ML) model, as an alternative to the physically based Soil and Water Assessment Tool (SWAT) for predicting streamflow in the Rio Grande Headwaters near Del Norte, a snowmelt-dominated mountainous watershed of the Upper Rio Grande Basin. Remotely sensed data were used for the random forest machine learning analysis (RFML) and RStudio for data processing and synthesizing. The RFML model outperformed the SWAT model in accuracy and demonstrated its capability in predicting streamflow in this region. We implemented a customized approach to the RFR model to assess the model's performance for three training periods, across 1991–2010, 1996–2010, and 2001–2010; the results indicated that the model's accuracy improved with longer training periods, implying that the model trained on a more extended period is better able to capture the parameters' variability and reproduce streamflow data more accurately. The variable importance (i.e., IncNodePurity) measure of the RFML model revealed that the snow depth and the minimum temperature were consistently the top two predictors across all training periods. The paper also evaluated how well the SWAT model performs in reproducing streamflow data of the watershed with a conventional approach. The SWAT model needed more time and data to set up and calibrate, delivering acceptable performance in annual mean streamflow simulation, with satisfactory index of agreement (d), coefficient of determination (R^2), and percent bias (PBIAS) values, but monthly simulation warrants further exploration and model adjustments. The study recommends exploring snowmelt runoff hydrologic processes, dust-driven sublimation effects, and more detailed topographic input parameters to update the SWAT snowmelt routine for better monthly flow estimation. The results provide a critical analysis for enhancing streamflow prediction, which is valuable for further research and water resource management, including snowmelt-driven semi-arid regions.

Keywords: streamflow prediction; random forest machine learning; hydrologic modeling; water resource management; remote sensing data; climate change

Citation: Islam, K.I.; Elias, E.; Carroll, K.C.; Brown, C. Exploring Random Forest Machine Learning and Remote Sensing Data for Streamflow Prediction: An Alternative Approach to a Process-Based Hydrologic Modeling in a Snowmelt-Driven Watershed. *Remote Sens.* **2023**, *15*, 3999. https://doi.org/10.3390/rs15163999

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1. Introduction

Various modeling tools have been developed and widely used worldwide to predict hydrologic responses [1,2] and are deemed essential for water resource management [3,4], particularly in areas where the hydrologic data or information is limited [5–7]. Monitoring

applied sciences

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Article

Nitrogen and Phosphorus Discharge Loads Assessment Using the SWAT Model: A Case Study of the Shatt Al-Arab River Basin

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Abstract: Understanding the link between land use/land cover (LULC) patterns and water quality can establish guidelines for non-point source pollution management and sustainable development. The transboundary Shatt Al-Arab river basin (Iraq-Iran) suffers from nutrient pollution problems. This study aimed to estimate flow volume, nitrogen, and phosphorus pollution in this basin and how such pollution relates to LULC and flow volume using the Soil and Water Assessment Tool (SWAT) model. The data used in the SWAT model were the Digital Elevation Model (DEM), slope, parent materials of soil, LULC, and weather data (i.e., precipitation, relative humidity, temperature, solar radiation, and wind speed). The results showed that from 2004 to 2021, the annual Total Nitrogen (TN) and Total Phosphorus (TP) outputs were 618 and 140 kg km^{-2}, respectively. The TN discharge load ranged from 27 to 6500 kg km^{-2} yr^{-1}, while the TP discharge load ranged from 1 to 1600 kg km^{-2} yr^{-1}. Redundancy Analysis (RDA) revealed that cropland and urban cover ratios were positively correlated with the annual TN and TP discharge loads. On the contrary, shrubland and bare land ratios were negatively correlated with the annual TN and TP discharge loads. Results showed that flow volume is positively correlated with precipitation. Both annual TN and TP discharge loads exhibited a positive correlation with flow volume and a negative correlation with subbasin area. The highest annual TN and TP discharge loads were in the middle parts of the basin, where the cultivated land and construction land are concentrated and the flow volume is high. Thus, findings suggest that the basin is sensitive to shifts in flow volume associated with global climate change and to shifts in LULC change. No study for nutrient discharge load assessment for the entire Shatt Al-Arab river basin has been performed before. Hence, the novel contribution of this study will guide the hydrologists and water resource planners in the basin to establish effective water policies, climate change mitigation strategies, and environmental change adaptation strategies.

Keywords: land use/land cover; water quality; SWAT model; redundancy analysis; Shatt Al-Arab river basin

Citation: Salim Aoubid, H.; Opp, C. Nitrogen and Phosphorus Discharge Loads Assessment Using the SWAT Model: A Case Study of the Shatt Al-Arab River Basin. *Appl. Sci.* **2023**, *13*, 8376. https://doi.org/10.3390/app13148376

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1. Introduction

The Shatt Al-Arab river, the primary freshwater source in a relatively arid region [1], delivers lifeline advantages for millions of people in its basin [2]. The river's basin encompasses the major oil and gas fields in Iraq and Iran. The oil industry is the main artery for the federal budget in these two countries. The river provides water for domestic, industrial, agricultural, transportation, natural ecosystems, and recreational purposes [3]. Moreover, the river is the main freshwater source for the gulf and is essential to maintaining the marine ecosystems along the gulf's northeastern coasts [4,5]. However, the oil industry, which has grown sharply in the last two decades, accompanied by population growth, has resulted in rigorous environmental impairment that not only threatened the environment but also made it impossible to maintain the consequent economic growth [3,6]. Industrial

sustainability

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Article

Assessing the Implication of Climate Change to Forecast Future Flood Using SWAT and HEC-RAS Model under CMIP5 Climate Projection in Upper Nan Watershed, Thailand

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Abstract: Climate change will affect Southeast Asian countries, particularly Thailand. There are still insufficient studies on rainfall, streamflow, and future floods in the Upper Nan Watershed, northern Thailand. This study examined how future climate change will affect the rainfall, streamflow, and flooding in the Upper Nan Watershed. SWAT and HEC-RAS models were utilized to assess the future streamflow and flooding in this area. The models used data from 1980–2020, which were taken from seven Upper Nan meteorological stations and two discharge stations. In this study, the impact of future climate change was predicted using three GCMs, under RCP4.5 and RCP8.5 scenarios. The historical data analyzed in this study indicated that rainfall in the study area has a positive trend. Climate change will increase further, from 18% to 19%, which will cause more fluctuations and lead to wetter conditions, both in the wet and dry seasons. Climate change delayed the hydrograph peak and the SWAT-modelled streamflow in the N1 and N64 stations by between 0.3% and 5.1%. RCP8.5 inundated all of the stations more than RCP4.5. Our models showed that in the medium future (2041–2060), the inundated area will be similar to that during the 100-year flood probability. Thus, monitoring and preparation are necessary to avoid repeating the considerable 2011 flood losses in Thailand.

Keywords: climate change; flood assessment; HEC-RAS model; rainfall assessment; SWAT model; Upper Nan Watershed

Citation: Satriagasa, M.C.; Tongdeenok, P.; Kaewjampa, N. Assessing the Implication of Climate Change to Forecast Future Flood Using SWAT and HEC-RAS Model under CMIP5 Climate Projection in Upper Nan Watershed, Thailand. *Sustainability* **2023**, *15*, 5276. https://doi.org/10.3390/su15065276

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1. Introduction

In the future, it has been predicted that the hydrologic cycle will be disturbed by climate change [1–3]. In some areas, the water levels are predicted to increase [4–6], while in others they are predicted to decrease [7,8]. Furthermore, due to the disturbances, the water balance will also be altered and will fluctuate more, which will drive more frequent and intense extreme weather events [1]. Such events could lead to hydro-meteorological disasters, including floods.

Flooding is the most common natural disaster, globally. As reported by Shen [9], globally, between 1900 and 2015, hydrological disasters, including floods, occurred more than other natural disasters. Floods not only occur in developing countries, such as Indonesia [10] and Thailand [11] but also occur in developed countries, for example, in Germany [12] and Japan [13]. Financial losses, injuries, and death tolls driven by flood events are rapidly increasing and are projected to continue to increase in the future [9]. According to Dottori et al. [14], a 1.5 °C air temperature rise could increase human deaths by 76%, flood destruction by 200%, and welfare by 0.6%. Moreover, a 2 °C air temperature increase would double direct economic damage, deaths, and welfare losses caused by flooding. Thus, flood assessment is crucial in mitigating their future impacts.

Recently, interest in studying the progression of climate change has been rising tremendously around the globe [15–18]. The future of climate change needs to be understood

water

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Article

Simulating the Hydrological Processes under Multiple Land Use/Land Cover and Climate Change Scenarios in the Mahanadi Reservoir Complex, Chhattisgarh, India

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Abstract: Land use/land cover (LULC) and climate are two crucial environmental factors that impact watershed hydrology worldwide. The current study seeks to comprehend how the evolving climate and LULC patterns are impacting the hydrology of the Mahanadi Reservoir catchment. A semi-distributed Soil and Water Assessment Tool (SWAT) model was utilized to simulate various water balance elements. Twelve distinct scenarios were developed by combining three different climatic data periods (1985–1996, 1997–2008, and 2009–2020) with four sets of land use maps (1985, 1995, 2005, and 2014). The SWAT model demonstrated strong performance in simulating monthly stream flows throughout the calibration and validation phases. The study reveals that changes in LULC have a distinct effect on the environment. Specifically, the changes in LULC lead to heightened streamflow and reduced evapotranspiration (ET). These changes are mainly attributed to amplified urbanization and the diminished presence of water bodies, forest cover, and barren land within the Mahanadi Reservoir catchment. The combined impact of climate change and LULC shifts reveals complex interactions. Therefore, the present study offers an understanding of how changes in climate and land use over the past few decades have influenced the hydrological behavior of the Mahanadi Reservoir catchment in Chhattisgarh. The findings of this study have the potential to offer advantages to governmental bodies, policymakers, water resource engineers, and planners seeking effective strategies for water resource management. These strategies would be particularly relevant in the context of climate change and land use/land cover changes in ecological regions similar to those of the Mahanadi Reservoir catchment. In addition, a rational regulatory framework for land use patterns is essential for assisting stakeholders in managing water resources and appropriately developing the entire catchment.

Keywords: ecological system; land use and land cover (LULC); SWAT model; typical years; urbanization; water resources

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Citation: Verma, S.; Verma, M.K.; Prasad, A.D.; Mehta, D.; Azamathulla, H.M.; Muttil, N.; Rathnayake, U. Simulating the Hydrological Processes under Multiple Land Use/Land Cover and Climate Change Scenarios in the Mahanadi Reservoir Complex, Chhattisgarh, India. *Water* **2023**, *15*, 3068. https://doi.org/10.3390/w15173068

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1. Introduction

Climate change is a globally recognized phenomenon that has gained widespread acceptance within the scientific community [1,2]. This phenomenon is anticipated to change patterns of precipitation and temperatures worldwide, leading to drier conditions in certain

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Application of hydrological models in climate change framework for a river basin in India

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ABSTRACT

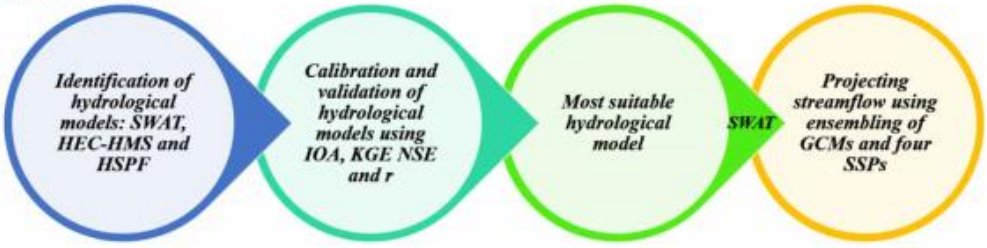
Soil Water Assessment Tool (SWAT), Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS), and Hydrologic Simulation Program Fortran (HSPF) are explored for streamflow simulation of Lower Godavari Basin, India. The simulating ability of models is evaluated using four indicators. SWAT has shown exceptional simulating ability in calibration and validation compared to the other two. Accordingly, SWAT is used in the climate change framework using an ensemble of 13 Global Climate Models and four Shared Socioeconomic Pathways (SSPs). Three time segments, near-future (2021–2046), mid-future (2047–2072), and far-future (2073–2099), are considered for analysis. Four SSPs show a substantial increase in streamflow compared to the historical period (1982–2020). These deviations range from 17.14 (in SSP245) to 28.35% (in SSP126) (near-future), 31.32 (SSP370) to 43.28% (SSP585) (mid-future), and 30.41 (SSP126) to 70.8% (SSP585) (far-future). Across all timescales covering 948 months, the highest projected streamflows observed in SSP126, SSP245, SSP370, and SSP585 were 4962.36, 6,108, 6,821, and 6,845 m^3/s, respectively. Efforts are also made to appraise the influence of multi-model combinations on streamflow. The present study is expected to provide a platform for holistic decision-making, which helps develop efficient basin planning and management alternatives.

Key words: global climate models, HEC-HMS, HSPF, Lower Godavari Basin, streamflow, SWAT

HIGHLIGHTS

- SWAT performed ahead of HEC-HMS and HSPF in training and testing for all chosen indicators.
- Four SSPs show a substantial increase in streamflow compared to the historical period (1982–2020).
- Across all timescales, the highest projected streamflows observed in SSP126, SSP245, SSP370, and SSP585 were 4962.36, 6,108, 6,821, and 6,845 m^3/s, respectively.
- Four multi-model combinations were developed.

GRAPHICAL ABSTRACT



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Satriagasa, M.C., Tongdeenok, P. y Kaewjampa, N. (2023). Assessing the Implication of Climate Change to Forecast Future Flood Using SWAT and HEC-RAS Model under CMIP5 Climate Projection in Upper Nan Watershed, Thailand. Sustainability. [Online]. 15 (6). p.p. 5276. http://dx.doi.org/10.3390/su15065276

Verma, S., Verma, M.K., Prasad, A.D., Mehta, D. et al. (2023). Simulating the Hydrological Processes under Multiple Land Use/Land Cover and Climate Change Scenarios in the Mahanadi Reservoir Complex, Chhattisgarh, India. Water. [Online]. 15 (17). p.p. 3068. http://dx.doi.org/10.3390/w15173068

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B.8. WEPP

CG9. B8

1. Descripción

El Modelo del Proyecto de Predicción de Erosión de Agua (Water Erosion Prediction ProjectWEPP) es un modelo físico de simulación de erosión basado en los fundamentos de la hidrología, la botánica, la hidráulica y la erosión mecánica.

Este modelo fue desarrollado por un equipo multidisciplinar de científicos con el objetivo de reemplazar la Ecuación Universal de Pérdida de Suelo (Universal Soil Loss Equation-USLE) y ha sido utilizado de manera generaliza en Estados Unidos y el mundo.

El programa para que el modelo funcione requiere cuatro tipos de información de entrada: clima, topografía, suelo y uso (vegetación) para proporcionar como resultado varios tipos de productos. Éstos son el balance hídrico (escorrentía, flujo subsuperficial y evapotranspiración), desprendimiento y deposición del suelo en varios puntos a lo largo de una pendiente, aporte de sedimentos y crecimiento de la vegetación.

El modelo WEPP ha sido mejorado continuamente desde su primera entrega en 1995. Ha sido desarrollado por el Centro de Investigación Nacional de la Erosión del Suelo, dependiente del Departamento de Agricultura de los Estados Unidos (USDA). La última versión es la 2012.8 (agosto 2012).

Las principales investigaciones en las que se ha usado SWAT+ recientemente son Admas et al., 2022; Epple et al., 2022; Huang et al., 2023; Magalhães et al., 2023; Shen et al., 2023; Wang et al., 2023 y Wang et al., 2022.

2. Características técnicas

Programa	WEPP		
Versión	2012.8	Año	2012
Tipología	Modelación hidrológica		
Capacidades del programa	El Water Erosion Prediction Project (WEPP) es un programa informático de simulación continua que predice la pérdida de suelo y la deposición de sedimentos del flujo superficial en laderas y en canales de flujo concentrado y, por último, la deposición de sedimentos en embalses. Además, incluye un componente climático que utiliza un generador estocástico que proporciona información meteorológica diaria, una componente de hidrología que usa la ecuación de infiltración Green-Ampt, una componente de balance de agua diario, otra de crecimiento de la vegetación y una última de riego. El software calcula las distribuciones espaciales y temporales de la pérdida y deposición del suelo y proporciona estimaciones explícitas de cuándo y dónde está ocurriendo la erosión, ya sea en una ladera o en una cuenca hidrográfica		
Sistema operativo			
	Windows (32 bits)		
Tipo de sistema (arquitectura)	32 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	National Soil Erosion Research (United States Department of Agriculture-USDA)		
Web	https://www.fs.usda.gov/ccrc/tool/watershed-erosion-prediction-project-wepp		

3. Ejemplos de trabajos científicos

hydrology

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Soil Erosion, Sediment Yield, and Runoff Modeling of the Megech Watershed Using the GeoWEPP Model

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Abstract: Modeling soil erosion, sediment yield, and runoff are crucial for managing reservoir capacity, water quality, and watershed soil productivity. However, the monitoring and modeling of soil erosion and sedimentation rates in developing countries such as Ethiopia is not well practiced; thus, the reservoir capacity is diminishing at faster rates. In this study, the soil erosion, sediment yield, and runoff in the Megech watershed, Upper Blue Nile Basin, Ethiopia were modeled using the physically-based geospatial interface, the Water Erosion Prediction Project (GeoWEPP). The GoWEPP model was calibrated and validated at the Angereb sub-watershed and simulated to representative sites to capture the spatiotemporal variability of soil erosion and sediment yield of the Megech watershed. The model parameter sensitivity analysis showed that the hydraulic conductivity (Ke) for all soil types was found to be the dominant parameter for runoff simulation, while rill erodibility (Kr), hydraulic conductivity (Ke), critical shear stress (τc), and inter rill erodibility (Ki) were found to be sensitive for sediment yield and soil loss simulation. The model calibration (2000–2002) and validation (2003–2004) results showed the capability of the GeoWEPP model; with R^2 and NSE values, respectively, of 0.94 and 0.94 for calibration; and 0.75 and 0.65 for validation. In general, the results show that the sediment yield in the study watershed varied between 10.3 t/ha/year to 54.8 t/ha/year, with a weighted mean value of 28.57 t/ha/year. The GeoWEPP model resulted in higher sediment value over that of the design sediment yield in the study basin, suggesting the implementation of the best watershed management practices to reduce the rates of watershed sediment yield. Moreover, the mean soil loss rate for the Angerb sub-watershed was found to be 32.69 t/ha/year.

Keywords: GeoWEPP; soil loss; reservoirs; sediment yield; runoff

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1. Introduction

Soil erosion and siltation by water is a big problem in the world and its impact is more serious in a developing country such as Ethiopia due to intensive agriculture, overgrazing, and high population stress [1–3]. Soil erosion and sedimentation have two major consequences for water resources: onsite and offsite effects. One of the key offsite effects identified is reservoir capacity drop that brings inordinate challenges to use reservoirs sustainably to their design life due to the high rate of siltation [3–9]. Ref. [10] studied the influences of accelerated soil erosion on reservoir capacity loss at a faster rate and suggested catchment management, sediment flushing, and sediment routing as general mitigation measures. However, [11,12] identified that land and water management play an important role to combat life storage depletion and sustaining dams to their useful life in the highlands of the Ethiopian watershed. Reservoir sedimentation rates varied across reservoir size, watershed management interventions, and physiographic and climate conditions, but worldwide more than 1% of reservoir total capacity is lost annually [13,14]. The

remote sensing

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Review

A Review on the Possibilities and Challenges of Today's Soil and Soil Surface Assessment Techniques in the Context of Process-Based Soil Erosion Models

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Abstract: To investigate relevant processes as well as to predict the possible impact of soil erosion, many soil erosion modelling tools have been developed. The most productive development of process-based models took place at the end of the 20th century. Since then, the methods available to observe and measure soil erosion features as well as methods to inter- and extrapolate such data have undergone rapid development, e.g., photogrammetry, light detection and ranging (LiDAR) and sediment tracing are now readily available methods, which can be applied by a broader community with lower effort. This review takes 13 process-based soil erosion models and different assessment techniques into account. It shows where and how such methods were already implemented in soil erosion modelling approaches. Several areas were found in which the models miss the capability to fully implement the information, which can be drawn from the now-available observation and data preparation methods. So far, most process-based models are not capable of implementing cross-scale erosional processes and can only in parts profit from the available resolution on a temporal and spatial scale. We conclude that the models' process description, adaptability to scale, parameterization, and calibration need further development. The main challenge is to enhance the models, so they are able to simulate soil erosion processes as complex as they need to be. Thanks to the progress made in data acquisition techniques, achieving this aim is closer than ever, if models are able to reap the benefit.

Keywords: process-based soil erosion model; remote sensing; photogrammetric methods; tracing; soil surface measurement; soil assessment; soil erosion

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1. Introduction

Soil, a natural resource with essential functions to the ecosystem, has experienced extensive degradation over the past decades [1,2]. Soil erosion can lead to soil loss and eventually to the exposure of the underlying bedrock [3]. It represents a decisive process for degrading agricultural land and thus crop yield on a global scale [4–6]. Climate change causes an increase in frequency of extreme weather events and therefore leads to spatially differentiated changes in extent, intensity and frequency of soil erosion [7–10]. Alongside the direct impact of climate change, it also triggers indirect drivers of soil erosion, such as crop management or land use changes [9,10], varying greatly with the region [11–13].

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Article

Modified Numerical Method for Improving the Calculation of Rill Detachment Rate

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Abstract: A rational calculation of the rill detachment rate (RDR) and an accurate simulation of the rill detachment process are important for determining the model parameters of hillslope erosion. Here, we found a difference between RDRs calculated using different methods that cannot be ignored. This study proposes a modified numerical method based on the dataset of the measured sediment concentrations along the rill length over a saturated loess soil slope to improve the calculation of RDR. For the saturated loess soil slope, the modified numerical RDR reduced the relative error from 58.3% to 4.6%, thereby demonstrating the efficiency of the modified numerical method. Furthermore, datasets of previous studies on different soil types and rill width verified the accuracy and applicability of the modified numerical method. A measurement strategy with more sampling points set at the forepart of the rill is proposed to enhance the calculation accuracy of RDR in accordance with the absolute error distribution between numerical and modified numerical RDRs. This study contributes to the literature by correcting previous data, improving data for subsequent measurements, and supplying a basis for the accurate estimation of RDR for rill erosion modeling.

Keywords: detachment rate; rill erosion; WEPP model; modifying; rill length

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1. Introduction

Soil erosion, as a key environmental issue globally, can lead to land degradation [1] and landslides [2,3]. The soil erosion processes comprehensively include soil detachment, entrainment, transport, and deposition [4]. As an erosive subprocess, soil detachment is the first step of soil erosion [5,6]. The soil detachment rate is an indispensable index for determining the process-oriented soil erosion, and it is an important parameter in soil erosion models, directly affecting their accuracy [7,8]. Therefore, the accurate measurement of soil detachment rate is very important. Previous studies found that the soil detachment rate could be obtained using some models that contain hydraulic parameters, such as stream power [9], unit stream power [10], and flow shear stress [11]. Furthermore, some studies verified that stream power and shear stress were recommended to predict the soil detachment rate at tillage [12], hillslope [13,14], and road surface [15]. However, these hydraulic parameters were hard to measure and complicated calculation, such that the soil detachment rate was conducted with low accuracy [12–17]. Thus, a simply calculated, convenient, and exact parameter should be considered to calculate the soil detachment rate.

Rill erosion has been incorporated into process-based erosion models because it is an important process of hillslope erosion [18–20]. The rill detachment rate (RDR) is a fundamental parameter for determining the rill erosion model. Some studies focused on determining the soil detachment rate of the entire slope [21–23]. Zhou et al. [21] studied the effect of sediment-laden rill flow on the soil detachment process and found that flow

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Using the GeoWEPP Model to Predict Water Erosion in Micro-Watersheds in the Brazilian Cerrado

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Abstract: The GeoWEPP model has estimated water and soil losses caused by erosion at the watershed level in different parts of the world. However, this model was developed and its parameters have been adjusted for temperate climates, which are different from tropical climates such as those found in Brazil. Our study evaluated the performance of the GeoWEPP model in estimating soil erosion in three micro-watersheds in the Cerrado (i.e., savannah) of southeastern Mato Grosso state, Brazil. Major land uses modeled were soybean and corn cultivation, traditional pasture, and native vegetation. Input parameters for the GeoWEPP model involved climate, soil, land use and management, and topography. GeoWEPP was calibrated with input parameters for soil erodibility specified as interrill and rill soil erosion, soil critical shear stress, and saturated hydraulic conductivity obtained experimentally and estimated by internal routine equations of the GeoWEPP model. Soil losses observed in micro-watersheds with agriculture, pasture, and native vegetation were 0.11, 0.06, and 0.10 metric tons per hectare per year, respectively. GeoWEPP best modeled soil erosion for native vegetation and pasture, while over-estimating that for crops. Surface runoff was best modeled for crops versus native vegetation and pasture. The GeoWEPP model performed better when using soil erodibility input parameters.

Keywords: environmental impact; soil conservation; water erosion prediction; watershed; WEPP parameters

Citation: Magalhães, W.d.A.; Amorim, R.S.S.; Hunter, M.O.; Bocuti, E.D.; Di Loreto Di Raimo, L.A.; da Silva, W.M.; Hoshide, A.K.; de Abreu, D.C. Using the GeoWEPP Model to Predict Water Erosion in Micro-Watersheds in the Brazilian Cerrado. *Sustainability* **2023**, *15*, 4711. https://doi.org/10.3390/su15064711

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1. Introduction

Land use and occupation have undergone several transformations in recent decades, especially in emerging countries such as Brazil, as well as more globally. Studies on soil erosion have been essential for the management and conservation of the environment in general, especially in agricultural environments with higher erosion potential. Prior research has estimated soil loss in the order of 820 million metric tons per year in Brazil, considering not only annual crops but areas cultivated with pastures and perennial crops [1]. Another study estimated soil losses in Brazil to be around 616.5 million metric tons per year with annual crops alone [2]. Water erosion and nutrient runoff into water bodies are typical problems of agricultural activities [3]. Accelerated soil erosion has a global effect, and impacts on the emission of greenhouse gases such as carbon dioxide (CO_2), methane

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Response of Soil Detachment Rate to Sediment Load and Model Examination: A Key Process Simulation of Rill Erosion on Steep Loessial Hillslopes

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Abstract: The rate of soil detachment by water flow indicates soil erosion intensity directly. The exact relation between soil detachment rate and actual sediment load in water flow, however, is still unclear, and the existing relationships have not been adequately tested. The aims of the present study were to investigate the response of soil detachment rate to sediment load using rill flume data with loessial soil and to quantitatively examine the soil detachment equations in the WEPP and EUROSEM soil erosion models. Six slopes were combined with seven flow discharges to measure detachment rates under seven sediment loads using a rill flume with a soil-feeding hopper. Significant differences were found among the soil detachment rate by different sediment loads in low sediment load levels, but an insensitive response of soil detachment rate to sediment load was found under high levels of sediment load. The soil detachment rate was proved to be negatively linearly correlated with sediment load. The rill detachment equation in the WEPP model predicted the soil detachment rate by rill flow very well under our experiment condition. The soil detachment equation in the EUROSEM model underestimated the detachment rates under controlled conditions, but removing the setting velocity from the equation greatly improved prediction. Further experiments that could reflect the dynamic convective detachment and deposition process need to be conducted to compare with the present examination results and to further understand rill erosion processes.

Keywords: soil erosion model; soil detachment; sediment load; WEPP model; EUROSEM model; rill flume experiment

Citation: Shen, N.; Wang, Z.; Zhang, F.; Zhou, C. Response of Soil Detachment Rate to Sediment Load and Model Examination: A Key Process Simulation of Rill Erosion on Steep Loessial Hillslopes. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2839. https://doi.org/10.3390/ijerph20042839

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1. Introduction

Soil erosion is a serious environmental problem worldwide, and results in the area of cultivated land decreasing, the soil quality declining, sediment deposition on riverbeds, and serious flooding disasters [1–7]. All the environmentally harmful consequences of soil erosion greatly threaten the sustainable development of human beings. Physically based prediction models of soil erosion are of great significance for erosion hazards prevention, the development of which requires a good understanding of the soil erosion process. Rill erosion is an important soil erosion type on hillslopes [8–10], and soil detachment of soil particles from the soil body by rill flow and sediment transport by rill flow are the key processes of rill erosion [11]. The rate of detachment directly indicates soil erosion intensity [12], and the soil detachment process provides sediment sources for transport processes. Along with the increase in sediment load in rill flow, the sediment transport process, in turn, may have feedback effects on the soil detachment process. However, the influence and relation of the actual sediment load runoff transported on the soil detachment rate is still ambiguous, and the existing detachment model equations have not been adequately tested. The relationship between soil detachment rate and sediment load in rills

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A Mathematical Method for Estimating the Critical Slope Angle of Sheet Erosion

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Abstract: Estimating the critical slope angle (CSA) for sheet erosion is important for the precision estimation of sheet erosion and the development of erosion control practices. This study developed mathematical equations considering rainfall intensity and soil infiltration to efficiently estimate both instantaneous (at a given instant during rainfall) and cumulative CSAs, while also providing a valuable explanation for the change in CSA. The mathematical equations were consistent with observations from runoff plots (NSE = −1.01) of loess soils from Zhangjiakou (China) and simulation results (NSE = 0.96) from the Water Erosion Prediction Project model for a loam soil in Montana (USA). Estimated instantaneous CSA determined by the mathematical equations increased as the ratio of rainfall intensity to soil infiltration (I/f) increased, resulting in higher observed cumulative CSA after heavy versus normal rainfall events. Heavy rainfall, compacted soil, and varying rainfall duration affected the CSA by changing the I/f ratio. Maximum instantaneous CSA provided a better prediction of changes in soil erosion dynamics than that obtained from CSAs determined by field observations or experimental simulations. The mathematical equations illustrate the underlying physical mechanisms by which rainfall intensity and soil infiltration affect the CSA through changing the shear stress of overland flow. The results of this study provide critical information for guiding the development of effective soil erosion control strategies.

Keywords: sheet erosion; rainfall–infiltration dynamics; critical slope angle; shear stress analysis; soil erosion control

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1. Introduction

Soil erosion is a persistent global environmental threat causing fertilizer loss, soil degradation, and a reduction in soil water/nutrient storage capacity, which in turn leads to a deterioration of water quality, decreased land productivity, and enhanced flooding [1–3]. Although many countries have adopted a series of soil erosion control measures, such as returning farmland to forests, building terraces, and increasing vegetation coverage, soil erosion remains a severe problem. Globally, soil erosion in 2012 amounted to an estimated 35.9 billion tons and exhibited an increase of 2.5% compared with 2001, driven primarily by cropland expansion [4]. Increased soil erosion affects sustainable agricultural development and is identified as a major environmental issue worldwide [4,5].

As the primary form of overland flow erosion, sheet erosion is a common phenomenon along hillslopes during rainfall events [6–8]. Sheet erosion is affected by many factors, such as vegetation/residue cover, soil texture and infiltration, rainfall intensity, slope length, and slope angle [6,9–11]. Unlike other factors, the relationship between slope angle and sheet erosion is not monotonic but increases at first and then decreases at higher slope angles [12,13]. As such, there is a unique slope angle, termed the critical slope angle (CSA),

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Adapting the WEPP Hillslope Model and the TLS Technology to Predict Unpaved Road Soil Erosion

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Abstract: Unpaved road erosion have been recognized as important sediment sources in a watershed. To evaluate where and when road erosion occurs, the soil loss along road segments should be precisely predicted with process-based erosion models. Methods: The hillslope version of the Water Erosion Prediction Project (WEPP) was used to estimate soil loss from 20 typical road segments in the red soil region of South China. Terrestrial laser scanning (TLS)-measured soil losses were used to validate the model simulations. The results showed that the WEPP model could reasonably predict the total soil loss in relatively short (less than 100 m) and gentle (slope gradient lower than 10%) road segments. In contrast, soil loss would be underestimated for long or steep road segments. Detailed outputs along roads revealed that most of the peak soil loss rates were underestimated. It might due to the linear critical shear stress theory in the WEPP model. Additionally, the lack of upstream flow was found to be connected to the relatively low model efficiency. Nevertheless, the WEPP simulation could accurately fit erosion trend and predict the peak soil loss positions along road segments. Conclusions: The WEPP model could be adopted to evaluate the erosion risk of unpaved roads in the red soil region of South China.

Keywords: road erosion; erosion modelling; WEPP; terrestrial laser scanning; South China

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1. Introduction

Unpaved roads are common man-made geographical features that are distributed in agricultural or forested watersheds [1]. Road construction will change the underlying topography and alter the surface hydrology [2]. In turn, runoff generation is enhanced and results in a higher soil loss risk than that in other land-use types, such as farmland [3,4]. Furthermore, roads may accumulate, deliver, or increase sediment in runoff [5,6]. Therefore, unpaved roads have been reported to contribute a large proportion of sediment yield in a watershed, although they generally occupy a small fraction of the area [3,6–9]. Road-related sediment that is routed to water bodies such as lakes and rivers can cause serious damage to the aquatic environment and impair the beneficial uses of surface water resources [10]. Thus, road erosion should be considered one of the main sediment sources and should be properly evaluated [11–14].

Soil erosion models are effective tools for road erosion evaluation [15]. During the last 20 years, different models have been applied and developed in road-related soil loss prediction. For example, the USLE (Universal Soil Loss Equation) [16] and its modifications have been used to estimate sediment production from forest roads [17]. Scientists in North America have developed several empirical models to predict annual road sediment; examples include the SEDMODL (https://www.ncasi.org/resource/sedmodl-2-0/, accessed on 30 June 2022) [18], WARSEM [19], ROADMOD [20] and READI [13]. Some of these models

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C. ANÁLISIS DE IMÁGENES Y TELEDETECCIÓN

C.1. IMAGEJ

CG9. C1

1. Descripción

ImageJ es un programa Java de procesamiento de imágenes de dominio público inspirado en el programa para Macintosh *NIH Image*. Este programa originario fue desarrollado por la Subdirección de Servicios de Investigación (Research Services Branch – RSB) del Instituto Nacional de Salud Mental (National Institute of Mental Health – NIMH) que forma parte de los Institutos Nacionales de Salud de los Estados Unidos (National Institutes of Health – NIH) y ha sido reemplazado por ImageJ, que se ejecuta en Macintosh, Linux y Windows.

Este software puede mostrar, editar, analizar, procesar, guardar e imprimir imágenes de 8, 16 y 32 bits. Puede leer muchos formatos de imagen, incluidos TIFF, GIF, JPEG, BMP, DICOM, FITS y RAW. Es un programa multiproceso por lo que las operaciones que consumen mucho tiempo, como la lectura de archivos de imagen, se pueden realizar en paralelo con otras operaciones.

Puede calcular áreas y estadísticas de píxeles seleccionadas por el usuario además de medir distancias y ángulos. Permite crear histogramas de densidad y perfiles lineales. Admite funciones estándar de procesamiento de imágenes como manipulación del contraste, nitidez, suavizado, detección de bordes y filtrado. Por otra parte, también hace transformaciones geométricas como escalado, rotación y volteos.

ImageJ se diseñó con una arquitectura abierta que proporciona extensibilidad a través de complementos Java. Los complementos de adquisición, análisis y procesamiento personalizados se pueden desarrollar usando el editor integrado de ImageJ y el compilador de Java. Los complementos implementados por el usuario permiten resolver casi cualquier problema de procesamiento o análisis de imágenes.

Este programa se está desarrollando en Mas OS X usando su editor y el compilador de Java, además del editor BBEdit y herramienta de compilación Ant. El código fuente está disponible de manera gratuita. El autor de ImageJ, Wayne Rasband, trabaja en la Subdivisón de Servicios de Investigación (RSB) del Instituto de Salud Mental (INH) de Maryland (Estados Unidos).

Las principales investigaciones en las que se ha usado ImageJ recientemente son Adamopoulos y Rinaudo, 2021; Beer et al., 2023; Cafaro et al., 2023; Carrasco-Rueda y Loiselle, 20020; El-Kahaled et al., 2022; Mikulec et al., 2023 y Santos et al, 2023.

2. Características técnicas

Programa	ImageJ		
Versión	1.54g	Año	2023
Tipología	Análisis de imágenes		
Capacidades del programa	Programa de procesamiento de imagen digital que puede mostrar, editar, analizar, procesar, guardar e imprimir imágenes de 8, 16 y 32 bits. Puede leer un amplio espectro de formatos de imagen incluyendo: TIFF, GIF, JPEG, BMP, DICOM… Puede medir píxeles, distancias, ángulos; crear histogramas de densidad y perfiles lineales. Posee funciones de contraste, nitidez, suavizado…		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
	macOS X (64 bits y arm M1)		
Tipo de sistema (arquitectura)	32 y 64 bits arm M1	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	National Institute of Health, NIH (USA)		
Web	https://wsr.imagej.net/ij/index.html		

3. Ejemplos de trabajos científicos

buildings

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Article

Combining Multiband Imaging, Photogrammetric Techniques, and FOSS GIS for Affordable Degradation Mapping of Stone Monuments

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Abstract: The detailed documentation of degradation constitutes a fundamental step for weathering diagnosis and, consequently, for successful planning and implementation of conservation measures for stone heritage. Mapping the surface patterns of stone is a non-destructive procedure critical for the qualitative and quantitative rating of the preservation state. Furthermore, mapping is employed for the annotation of weathering categories and the calculation of damage indexes. However, it is often a time-consuming task, which is conducted manually. Thus, practical methods need to be developed to automatize degradation mapping without significantly increasing the diagnostic process's cost for conservation specialists. This work aims to develop and evaluate a methodology based on affordable close-range sensing techniques, image processing, and free and open source software for the spatial description, annotation, qualitative analysis, and rating of stone weathering-induced damage. Low-cost cameras were used to record images in the visible, near-infrared, and thermal-infrared spectra. The application of photogrammetric techniques allowed for the generation of the necessary background, that was elaborated to extract thematic information. Digital image processing of the spatially and radiometrically corrected images and image mosaics enabled the straightforward transition to a spatial information environment simplifying the development of degradation maps. The digital thematic maps facilitated the rating of stone damage and the extraction of useful statistical data.

Keywords: stone degradation; weathering damage; low-cost sensors; multiband imaging; photogrammetry; digital image processing; mapping; FOSS; GIS; heritage conservation

Citation: Adamopoulos, E.; Rinaudo, F. Combining Multiband Imaging, Photogrammetric Techniques, and FOSS GIS for Affordable Degradation Mapping of Stone Monuments. *Buildings* **2021**, *11*, 304. https://doi.org/10.3390/buildings11070304

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1. Introduction and Background

A substantial fraction of the historic built environment is made of stone. Thus, stone monuments are an integral part of our heritage and our societies' continuity. Moreover, their presence affects everyone because of the essential historical values they possess tied to religion, culture, aesthetics, and building techniques of their construction period. Therefore, preserving stone monuments is critical in maintaining an essential historical resource and upholding a societal identity vital for future generations.

Natural stone materials (as, for example, limestone and marble) suffer from complex weathering processes that lead to degradation [1,2], which imposes significant challenges to ensuring the preservation of the historic build environment. Weathering of building and construction stone materials depends on intrinsic and extrinsic factors, which interact, causing degradation at different rates [3]. Environmental elements (past and present), anthropogenic parameters, physical properties of stone, and previous conservation interventions are all factors that contribute to stone-built heritage weathering [4–6]. However, understanding the weathering processes of stone is an intricate task that requires continuous interdisciplinary monitoring of the above parameters [7] and proves essential for the decision making regarding suitable and compatible conservation interventions [8].

processes

MDPI

Article

Visual Impact of Renewable Energy Infrastructure: Implications for Deployment and Public Perception

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Abstract: This study focuses on the specific topic of assessing the negative visual impacts associated with renewable energy infrastructure that may prevent their wider deployment in energy mix. The main objective of the paper is to quantify the perception of the visual impact of renewable energy infrastructure and to estimate potential changes in the visitation of a location after the construction of power plants. The research was conducted using a questionnaire survey in which 449 respondents evaluated edited photographic materials of seven locations with a fictitious power plant. The collected data served as input for the statistical testing of eight defined hypotheses using the U-Mann–Whitney test. The results confirmed trends regarding the influence of age, educational level, and power plant proximity on the overall acceptance of renewable energy infrastructure. Landscape-forming factors affecting the acceptance rate of power plants were also defined at the local level.

Keywords: renewable energy infrastructure; visual impacts; tourism; questionnaire survey; Slovak Republic

check for updates

Citation: Beer, M.; Rybár, R.; Gabániová, Ľ. Visual Impact of Renewable Energy Infrastructure: Implications for Deployment and Public Perception. *Processes* **2023**, *11*, 2252. https://doi.org/10.3390/pr11082252

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Published: 26 July 2023

1. Introduction

In recent years, the state of various components of the environment and society can be characterized by the word crisis. While we have moved on from the term global warming to climate change, the current environmental problems extend beyond climate change and its negative impacts. Therefore, a more appropriate term for the current state is environmental poly-crisis. Although the negative impacts on the environment, such as pollution [1], deforestation and biodiversity loss [2], ocean acidification [3], or ozone layer depletion [4], are significant, the most significant threat is climate change. According to the latest report from The Intergovernmental Panel on Climate Change [5], the consequences of climate change on society are alarming, and there is only a small chance of fully reversing them. The trajectories of greenhouse gas emissions and the resulting increase in global temperature indicate scenarios of future development that are rather negative [6]. One way to mitigate climate changes and global temperature rise is to reduce the use of fossil fuels, which are associated with the emission of a large volume of greenhouse gases [7]. In some areas, reducing the use of fossil fuels is limited by current technology, such as cement production, maritime and air transport, but some areas can operate with significant restrictions on the consumption of fossil fuels, such as electricity production using nuclear energy or renewable energy sources (hereafter referred to as RES), personal transport using electromobility or biofuels [8–10], and others. Some areas could be cut off from fossil fuels due to an increased energy efficiency (e.g., residential housing) or due to the electrification of processes in case low-emission sources are used for electricity production (e.g., steel production [11]).

The prognoses of growth in the use of RES indicate a massive increase in installed capacity in almost all types of utilized technologies. A smaller increase is expected in the use of energy from sea waves and hydropower plants, where most of the potential for a

agriculture

MDPI

Article

Germination Response of Different Castor Bean Genotypes to Temperature for Early and Late Sowing Adaptation in the Mediterranean Regions

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Abstract: Germination of castor seeds of seven dwarf hybrid genotypes, compared to a 'Local' genotype, selected from a Tunisian population by the University of Catania well adapted to the Mediterranean environment, were studied at six different temperatures (8, 12, 16, 25, 32, and 40 °C). The results indicate that the optimal temperature (25 °C) and near-optimal temperature (32 °C) are the best temperatures for ensuring castor germination (final germination percentage (FGP) $\geq$ 82.81%). Furthermore, these temperatures positively influenced the vigour index (VI) and the radicle elongation. At a temperature of 8 °C, no germination occurred, while temperatures of 12 and 40 °C negatively affected the seed germination, which, in some genotypes, was null or negligible (<21.25%). A temperature of 16 °C allowed good results to be reached for the FGP and the other considered parameters. Overall, the dwarf hybrids performed better at high temperatures than at low temperatures, thus, making them suitable for late sowings, with the exception of the genotype 'C1020', which resulted the best performance at 16 and 40 °C, being suitable for both early and late sowings. On the other hand, the 'Local' castor genotype, being the best-performing genotype at 12 and 16 °C, and the most tolerant to low temperature (base temperature (*T*b) 12.1 °C), could be used in the early sowing in spring.

Keywords: cardinal temperatures; dwarf hybrids; seed germination; seed vigour; synchrony

Citation: Cafaro, V.; Alexopoulou, E.; Cosentino, S.L.; Patanè, C. Germination Response of Different Castor Bean Genotypes to Temperature for Early and Late Sowing Adaptation in the Mediterranean Regions. *Agriculture* **2023**, *13*, 1569. https://doi.org/10.3390/agriculture13081569

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1. Introduction

Germination is a key stage in the establishment of plants. Germination consists of the activation of the metabolic mechanisms of the seed, which leads to the birth of a new seedling. To obtain the germination of a mature seed, three conditions should be satisfied: (1) the seed must be vital; (2) seed environmental requirements must be appropriate; and (3) any form of primary dormancy must be overcome.

The germination process begins with the absorption of water by the dry seed and ends with the elongation of the embryo [1]. During the imbibition, the seed is not uniformly moistened and this stage can be divided into two steps: the first one comprehends the hydration of the outer part of the seed, while the second includes the hydration of the inner part, the activation of metabolic processes, and, ultimately, the radicle extrusion through the structures surrounding the embryo [2]. Environmental factors such as soil moisture, temperature, oxygen, light, and pH influence seed germination in wild and cultivated plants [3]. In particular, optimal rates of seed germination and, consequently, plant establishment, are the first conditions required to achieve adequate levels of crop productivity, even under harsh weather conditions [4]. Therefore, it is important to analyse

diversity

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Article

Dimensions of Phyllostomid Bat Diversity and Assemblage Composition in a Tropical Forest-Agricultural Landscape

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Abstract: Tropical rainforests are suffering rapid habitat loss with large extensions of land transformed into agriculture. We wanted to know whether the type of agricultural activity in forest-agricultural landscapes affects how species composition as well as taxonomic and functional dimensions of diversity respond. We worked in the Amazon forests of southeast Peru and used bats as model organisms. We sampled mosaics characterized by forest adjacent to papaya plantations or cattle pastures. At each sampling site we established a transect in each of the three different vegetation types: forest interior, forest edge and agricultural land. We found that vegetation type was a better predictor of species composition than the type of agricultural land present. Vegetation structure characteristics explained differences in bat species composition between forest interior and edge. Agricultural land type chosen was not irrelevant as we found higher estimated species richness in papaya than in pasture sites. Agricultural land type present in a site and vegetation type affected functional diversity, with both agricultural land types showing a lower number of functionally distinct species than forests. We found papaya plantation sites showed species more evenly dispersed in trait space, suggesting they do better at conserving functional diversity when compared to cattle pasture sites. We demonstrate that sites that harbor agricultural activities can maintain a considerable proportion of the expected bat diversity. We note that this region still has large tracts of intact forest adjacent to agricultural lands, which may explain their ability to maintain relatively high levels bat diversity.

Keywords: functional diversity; land-use change; Madre de Dios; papaya plantations; Peru

1. Introduction

In the era of the Anthropocene [1] human activities are affecting biological diversity globally [2]. Exploitation of natural resources, deforestation, and land-use change are among the most important drivers of habitat loss and reduction of biodiversity [3,4]. These changes have negative consequences for ecosystems and people that depend on these ecosystems due to the loss of ecological function and services [5,6]. These negative impacts are perhaps nowhere more pressing than in highly biodiverse regions such as the tropics.

In tropical rainforest, habitat loss is occurring rapidly [7] with large extensions of land transformed into agriculture (including crop and livestock farming and plantations). Cropland represents 12% of the world surface [8], while grazing for livestock production covers 25% [9]. Agriculture generally has

diversity

MDPI

Article

Comparative Evaluation of Free Web Tools ImageJ and Photopea for the Surface Area Quantification of Planar Substrates and Organisms

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Abstract: Biological imaging is an essential tool to visualise and obtain reference data. In this context, the programme ImageJ has been widely used in many disciplines to determine the surface areas of planar biological samples in marine and aquatic experimental biology. Despite its range of advantages, ImageJ is relatively time-consuming, because of the need to manually select the target areas for quantification. Hence, we here evaluated the freeware programme Photopea as a potential alternative by comparing the accuracy and time required for the surface area quantification of exemplary algae compared with established ImageJ analysis. Our results show that Photopea is equally accurate as ImageJ, but 45% more time efficient. This time efficiency originates from using colour contrast that reduces the time needed to analyse each picture. Photopea thus offers an accurate, rapid, and cost-free tool to easily obtain reference data from field and laboratory experiments. This tool is particularly useful for experiments with an extensive sample size of specimens and thus can increase the power of study results.

Keywords: image processing; surface area determination; Adobe Photoshop; biological imaging

Citation: El-Khaled, Y.C.; Kler Lago, A.; Mezger, S.D.; Wild, C. Comparative Evaluation of Free Web Tools ImageJ and Photopea for the Surface Area Quantification of Planar Substrates and Organisms. *Diversity* **2022**, *14*, 272. https://doi.org/10.3390/d14040272

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1. Introduction

Quantitative and computational imaging has evolved at an unprecedented pace, offering seemingly limitless possibilities for a wide range of scientific fields. Particularly within the field of biological imaging, novel computational technologies together with tools in microscopy [1], mass spectrometry [2] and others [3] are currently a powerful way to make scientific progress accessible and visible. A key player in the field of biological imaging is the pioneer scientific image processing programme 'ImageJ' (previously known as NIH Image) first introduced in 1987 [4,5]. The reasons for the programme's success are as wide-ranging as the programme's span of applications, proven by its almost 16,000 citations (to date), its improvements over the years through the introduction of new plug-ins, its straightforward handling and by being an open access software [3,4].

ImageJ is commonly used in the field of aquatic and marine experimental biology, for example, to quantify coral tissue loss [6] or to determine the surface area of biological specimens [7,8]. Concerning the latter, biological specimens are often irregularly shaped, and so are the parts of the images to be analysed. ImageJ offers a range of image processing tools; however, accuracy may vary, and it is particularly time-consuming for irregular, cryptically shaped and coloured images.

One of many underlying (and highly discussed) pillars of science is the concept of either direct (i.e., identical experimental conditions) or conceptual (i.e., adjusted experimental conditions) replication [9]. Despite still being discussed, a consensus on the need to have a considerable number of biological replicates in the field of aquatic and marine experimental biology is shared among scientists [9]. This subsequently increases the generated data that are commonly referred to as specimens surface area to allow further statistical analysis,

processes

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Review

Green Techniques for Detecting Microplastics in Marine with Emphasis on FTIR and NIR Spectroscopy—Short Review

Vlatka Mikulec [1], Petra Adamović [2], Želimira Cvetković [1,*], Martina Ivešić [1] and Jasenka Gajdoš Kljusurić [3]

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Abstract: The amount of microplastics (MPs) present in marine ecosystems are a growing concern, with potential impacts on human health because they are associated with an increase in the ecotoxicity of certain foods, such as fish. As a result, there has been a growing interest in developing effective methods for the analysis of MPs in marine waters. Traditional methods for MP analysis involve visual inspection and manual sorting, which can be time-consuming and subject to human error. However, novel methods have been developed that offer more efficient and accurate analyses. One such method is based on spectroscopy, such as Fourier transform infrared spectroscopy (FTIR). Another method involves the use of fluorescent dyes, which can selectively bind to microplastics and allow for their detection under UV light. Additionally, machine learning approaches have been developed to analyze large volumes of water samples for MP detection and classification. These methods involve the use of specialized algorithms that can identify and classify MPs based on their size, shape, and texture. Overall, these novel methods offer more efficient and accurate analyses of MPs in marine waters, which is essential for understanding the extent and impacts of MP pollution and for developing effective mitigation strategies. However, there is still a need for continued research and development to optimize these methods and improve their sensitivity and accuracy.

Keywords: microplastics; marine pollution; health impact; microplastics analysis; ecotoxicological testing; novel methods; machine learning

Citation: Mikulec, V.; Adamović, P.; Cvetković, Ž.; Ivešić, M.; Gajdoš Kljusurić, J. Green Techniques for Detecting Microplastics in Marine with Emphasis on FTIR and NIR Spectroscopy—Short Review. *Processes* **2023**, *11*, 2360. https://doi.org/10.3390/pr11082360

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1. Introduction

Microplastics (MPs), defined as plastic waste with dimensions less than 5 mm [1,2], are recognized as an emerging environmental pollutant and have garnered considerable attention due to their possible negative effects on living organisms. MPs are categorized as main or secondary according to their sources. Marine litter, particularly MPs and nano-plastics (NPs), is widely disseminated and is recognized as a growing threat to the environment and human health. It is well recognized that maritime habitats are among the most damaged, and coastal zones are among the most polluted. Carpenter and Smith published the first paper warning about the presence of plastic pellets on the surface of the North Atlantic Ocean in 1972 [3]. Yet, it has only been in the last ten years that there has been a widespread increase in concern, both in the scholarly community and in society, about the impact of plastic-based pollution on the marine environment [4].

The proper approach for the identification of MPs should be selected based on the quantity of samples and the microplastic size range of interest; adopting a good identification method for microplastics is critical for analyzing microplastic contamination. Plastics are primarily classified based on physical qualities such as size, shape, and color [5]. The study of Coyle, Hardiman, and O'Driscoll presented polymers which (i) float as: Low-density polyethylene (LDPE), Polyethylene (PE), High-density polyethylene (HDPE), Polypropylene (PP), and Polystyrene (Expanded) (PS), and (ii) sink as: Polystyrene (PS),

sustainability

MDPI

Article

Hydrological Analysis of Green Roofs Performance under a Mediterranean Climate: A Case Study in Lisbon, Portugal

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Abstract: In this paper, the hydrological performance of eight pilot green roofs (GR) installed in Lisbon, Portugal, under a Mediterranean climate is analyzed. The pilot units were installed at Instituto Superior Técnico campus of Lisbon University. The pilots present different plant species and different substrate types, with some of the units incorporating recycled construction and demolition waste (RCW). The green roofs pilots' hydrologic performance was evaluated through the simulation of artificial precipitation events between March 2021 and July 2021. Considering the results obtained, it can be concluded that the inclusion of RCW in the substrate composition did not hinder the development of vegetation or the hydrological performance of GR. The results showed a rainfall water retention per event ranging from 37% to 100%, with an average rainfall retention of about 81%. The runoff delay ranged from 2 to 18 min, and the peak attenuation ranged from 30 to 100%. The results indicated that previous substrate moisture strongly influences the hydrological performance of GR. As the inclusion of RCW in the substrate composition promotes a more effective drainage of the substrate during dry conditions, it is considered that RCW may have positive impacts on GR's hydrological performance.

Keywords: green roofs; hydrological performance; Mediterranean climate; recycled construction and demolition waste substrate; urban stormwater management

Citation: Santos, M.L.; Silva, C.M.; Ferreira, F.; Matos, J.S. Hydrological Analysis of Green Roofs Performance under a Mediterranean Climate: A Case Study in Lisbon, Portugal. *Sustainability* **2023**, *15*, 1064. https://doi.org/10.3390/su15021064

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1. Introduction

The rapid and continuous urbanization, associated with climate change effects in terms of temperature increase, rainfall patterns and sea level rise, are causing several disturbances in urban areas, e.g., "heat island" effects, an increase in overflow discharges from combined sewer systems and more frequent flooding events.

In this context, more sustainable approaches are needed rather than simply grey techniques (e.g., larger sewers and more concrete detention tanks), including various forms of nature-based solutions, such as flooding parks, constructed wetlands, green walls, green ditches, bioswales, porous pavements and green roofs [1,2]. Those solutions fit into concepts and are known in Europe as Best Management Practices (BMPs), and they often include built components that mimic natural features, therefore constituting an environmentally beneficial approach that increases urban resilience [3,4].

The benefits from the implementation of BMPs in urban areas are diverse and include the mitigation of flood risks (due to attenuation, retardation and infiltration), climate regulation (mitigation of urban heat island effects and heatwaves) and reduction in pollution loads (associated with stormwater and overflow discharges), while promoting biodiversity and the incorporation of sociocultural services including recreational areas, as well as focusing on landscape and human well-being principles [5–7].

Green roofs (GR), which are a primary focus of this study, are to a great extent nature-based solutions [8]. GR are composed of a multilayered system that, from top to bottom, incorporates vegetation, technical substrate, filter layer, drainage layer, waterproofing layer and root barrier [9,10].

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Beer, M., Rybár, R. y Gabániová, Ľ. (2023). Visual Impact of Renewable Energy Infrastructure: Implications for Deployment and Public Perception. Processes. [Online]. 11 (8). p.p. 2252. http://dx.doi.org/10.3390/pr11082252

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Santos, M.L., Silva, C.M., Ferreira, F. y Matos, J.S. (2023). Hydrological Analysis of Green Roofs Performance under a Mediterranean Climate: A Case Study in Lisbon, Portugal. Sustainability. [Online]. 15 (2). p.p. 1064. http://dx.doi.org/10.3390/su15021064

C.2. GIMP

CG9. C2

1. Descripción

ImageJ es un programa Java de procesamiento de imágenes de dominio público inspirado en el programa para Macintosh *NIH Image*. Este programa originario fue desarrollado por la Subdirección de Servicios de Investigación (Research Services Branch – RSB) del Instituto Nacional de Salud Mental (National Institute of Mental Health – NIMH) que forma parte de los Institutos Nacionales de Salud de los Estados Unidos (National Institutes of Health – NIH) y ha sido reemplazado por ImageJ, que se ejecuta en Macintosh, Linux y Windows.

Este software puede mostrar, editar, analizar, procesar, guardar e imprimir imágenes de 8, 16 y 32 bits. Puede leer muchos formatos de imagen, incluidos TIFF, GIF, JPEG, BMP, DICOM, FITS y RAW. Es un programa multiproceso por lo que las operaciones que consumen mucho tiempo, como la lectura de archivos de imagen, se pueden realizar en paralelo con otras operaciones.

Puede calcular áreas y estadísticas de píxeles seleccionadas por el usuario además de medir distancias y ángulos. Permite crear histogramas de densidad y perfiles lineales. Admite funciones estándar de procesamiento de imágenes como manipulación del contraste, nitidez, suavizado, detección de bordes y filtrado. Por otra parte, también hace transformaciones geométricas como escalado, rotación y volteos.

ImageJ se diseñó con una arquitectura abierta que proporciona extensibilidad a través de complementos Java. Los complementos de adquisición, análisis y procesamiento personalizados se pueden desarrollar usando el editor integrado de ImageJ y el compilador de Java. Los complementos implementados por el usuario

permiten resolver casi cualquier problema de procesamiento o análisis de imágenes.

Este programa se está desarrollando en Mas OS X usando su editor y el compilador de Java, además del editor BBEdit y herramienta de compilación Ant. El código fuente está disponible de manera gratuita. El autor de ImageJ, Wayne Rasband, trabaja en la Subdivisón de Servicios de Investigación (RSB) del Instituto de Salud Mental (INH) de Maryland (Estados Unidos).

Este software se ha usado recientemente en los trabajos de Beißler y Hack, 2019; Cozzarini et al., 2023; Kalabiński et al., 2023; Kentsch et al., 2021; Klassert et al., 2015; Palmer et al., 2018 y Verdu-Candela et al., 2023.

2. Características técnicas

Programa	GIMP		
Versión	2.10.36	Año	2023
Tipología	Análisis de imágenes		
Capacidades del programa	GIMP (GNU Image Manipulation Program) es un programa de edición de imágenes digitales en forma de mapa de bits. Tiene herramientas que se utilizan para el retoque y edición de imágenes, dibujo de formas libres, cambiar el tamaño, recortar, hacer fotomontajes, convertir a diferentes formatos de imagen, y otras tareas más especializadas.		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
	macOS X (64 bits y arm M1)		
Tipo de sistema (arquitectura)	32 y 64 bits arm M1	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	Equipo de desarrollo de GIMP		
Web	https://www.gimp.org/		

3. Ejemplos de trabajos científicos

remote sensing

MDPI

Article

A Combined Field and Remote-Sensing Based Methodology to Assess the Ecosystem Service Potential of Urban Rivers in Developing Countries

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check for updates

Abstract: Natural rivers in urban areas bear significant potential to provide ecosystem services for the surrounding inhabitants. However, surface sealing by houses and street networks, urban drainage, disposal of waste and wastewater resulting from advancing urbanization usually lead to the deterioration of urban rivers and their riparian areas. This ultimately damages their ability to provide ecosystem services. This paper presents an innovative methodology for a rapid and low-cost assessment of the ecological status of urban rivers and riparian areas in developing countries under data scarce conditions. The methodology uses a combination of field data and freely available high-resolution satellite images to assess three ecological status categories: river hydromorphology, water quality, and riparian land cover. The focus here is on the assessment of proxies for biophysical structures and processes representing ecological functioning that enable urban rivers and riparian areas to provide ecosystem services. These proxies represent a combination of remote sensing land cover- and field-based indicators. Finally, the three ecological status categories are combined to quantify the potential of different river sections to provide regulating ecosystem services. The development and application of the methodology is demonstrated and visualized for each 100 m section of the Pochote River in the City of León, Nicaragua. This spatially distributed information of the ecosystem service potential of individual sections of the urban river and riparian areas can serve as important information for decision making regarding the protection, future use, and city development of these areas, as well as the targeted and tailor-made development of nature-based solutions such as green infrastructure.

Keywords: Urban rivers; ecological status; ecosystem services; developing countries; Nicaragua; nature-based solutions; green infrastructure; MAPURES; matrix approach

1. Introduction

Ecosystem services are the direct and indirect benefits that people derive from various types of ecosystems [1]. The maintenance and enhancement of ecosystem services is of central interest to societies. According to Potschin and Haines-Young [2], specific ecological and biophysical structures and processes, representing the status of an ecosystem (natural capital), can be conceptually linked to elements of human well-being [3]. A good ecosystem status provides adequate biophysical structures (e.g., for habitats) and facilitates ecological processes (e.g., primary production), while a deteriorated ecosystem status has less potential to provide such functions that ultimately lead to benefits to human beings as ecosystem services.

microplastics

MDPI

Article

Characterization of Large Microplastic Debris in Beach Sediments in the Po Delta Area

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Abstract: The use of single-use or disposable plastic objects has massively increased during the last few decades, and plastic has become the main type of litter found in marine environments. The Adriatic Sea is seriously prone to marine litter pollution, and it collects about one-third of all the freshwater flowing into the Mediterranean, mainly via the river Po. This study investigated the type and composition of large microplastic debris collected in different sites in the Po Delta area. Visual classification was performed by relevant criteria, while chemical composition was assessed by infrared spectroscopy. The main plastic fraction is composed of polyolefin (76%), followed by polystyrene (19%). This proportion roughly matches global plastic production, rescaled after excluding plastics with negative buoyancy: all the identified compounds have a specific gravity lower than that of the seawater. Fragments (irregularly shaped debris) represent the most abundant category fraction (85%), followed by pellets, which represent roughly 10% of the total. Overall, the results provided an insight into large microplastic pollution in beach sediments in the Po delta area.

Keywords: microplastics; marine litter pollution; Adriatic Sea; Po Delta; infrared spectroscopy

check for updates

Citation: Cozzarini, L.; Buoninsegni, J.; Corbau, C.; Lughi, V. Characterization of Large Microplastic Debris in Beach Sediments in the Po Delta Area. *Microplastics* **2023**, 2, 147–157. https://doi.org/10.3390/microplastics2010011

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1. Introduction

The use of plastics has massively increased during the last few decades and is nowadays widespread in everyday life, leading to a dramatic expansion in plastic production worldwide [1,2]. Since most of these objects are designed to be single-use or disposable parts, the increase in their use has inevitably been followed by a growth in the amount of generated plastic waste, which is leading to serious environmental consequences [3]. Due to this pattern, plastic has become the main type of litter affecting marine environments. The Mediterranean Sea is seriously subjected to marine litter pollution since it is heavily trafficked, it receives water from rivers from three continents and its coastlines are highly urbanized and used for industrial and tourist activities [4,5]. Moreover, the semienclosed geography of the Mediterranean basin inhibits litter dispersion to the other oceans [6]. As a consequence, the Mediterranean is considered one of the most polluted marine areas in the world regarding marine litter [7,8].

The Adriatic Sea, which is part of the Mediterranean Sea, is an elongated basin extending between Italy and the Balkan region for about 800 km from NW to SE. Among its peculiar characteristics, it has a high land-to-sea ratio and it collects about one-third of all the freshwater flowing into the Mediterranean (mainly via the river Po) [9–11]. In addition, the Adriatic Sea is considered the most polluted subregion of the Mediterranean Sea [12]. It has been estimated that about 40% of marine litter enters the Adriatic from rivers and an additional 40% derives from urban activities in coastal areas, while the remaining 20% is from fishing and shipping activities [13,14].

The greater portion of plastic waste derives from packaging, with the largest share composed of polyethylene (PE) and polypropylene (PP), followed by polyethylene terephthalate (PET) and with a minor contribution of polyvinyl chloride (PVC), polystyrene

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Article

Phase Equilibria and Critical Behavior in Nematogenic MBBA—Isooctane Monotectic-Type Mixtures

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Abstract: The transition from the isotropic (I) liquid to the nematic-type (N) uniaxial phase appearing as the consequence of the elongated geometry of elements seems to be a universal phenomenon for many types of suspensions, from solid nano-rods to biological particles based colloids. Rod-like thermotropic nematogenic liquid crystalline (LC) compounds and their mixtures with a molecular solvent (Sol) can be a significant reference for this category, enabling insights into universal features. The report presents studies in 4′-methoxybenzylidene-4-n-butylaniline (MBBA) and isooctane (Sol) mixtures, for which the monotectic-type phase diagram was found. There are two biphasic regions (i) for the low (*TP1*, *isotropic liquid-nematic coexistence*), and (ii) high (*TP2*, *liquid-liquid coexistence*) concentrations of isooctane. For both domains, biphasic coexistence curves' have been discussed and parameterized. For *TP2* it is related to the order parameter and diameter tests. Notable is the anomalous mean-field type behavior near the critical consolute temperature. Regarding the isotropic liquid phase, critical opalescence has been detected above both biphasic regions. For *TP2* it starts ca. 20 K above the critical consolute temperature. The nature of pretransitional fluctuations in the isotropic liquid phase was tested via nonlinear dielectric effect (*NDE*) measurements. It is classic (mean-field) above *TP1* and non-classic above the *TP2* domain. The long-standing problem regarding the non-critical background effect was solved to reach this result.

Keywords: liquid crystals; critical mixtures; critical opalescence; nonlinear dielectric effect; monotectic phase diagram

Citation: Kalabiński, J.; Drozd-Rzoska, A.; Rzoska, S.J. Phase Equilibria and Critical Behavior in Nematogenic MBBA—Isooctane Monotectic-Type Mixtures. *Int. J. Mol. Sci.* **2023**, *24*, 2065. https://doi.org/10.3390/ijms24032065

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Published: 20 January 2023

1. Introduction

Lars Onsager was the first who note and explain the appearance of the transition from the isotropic liquid to the predominantly uniaxial nematic (N) liquid crystalline mesophase as the consequence of the molecular alignment associated with the elongated geometry of elements, only weakly influenced by interactions [1,2]. The spontaneous appearance of the nematic mesophase, with the symmetry-related origin, occurs when the crossover concentration of rod-like elements crossovers a length-to-diameter (L/D) ratio above some model value. Flory reached a similar conclusion for a lattice model approach, paying more attention to specific attractive interactions [3]. Such general models expectations have been confirmed in numerous experimental systems, from colloids based on suspensions of solid nano and micro rods [4], to solutions of amphiphilic molecules [5], dispersions of high molecular weight molecules [6], mineral colloids [7] or colloidal suspensions of biological particles, for instance, cellulose [8], DNA [9], viruses [10], and further in cellular biomembranes [11].

In this diverse collection of qualitatively different systems, there is one common feature: rod-like uniaxial symmetry of building elements and a universal mechanism of transition from a homogeneous phase, or its analog, to an orientationally ordered nematic-type phase.

Such universality indicates the possibility of studying significant properties in selected experimentally convenient systems and considering the extension of conclusions to the entire category. The 'natural' candidate for such a model system with the inherent

sensors

MDPI

Article

Analysis of UAV-Acquired Wetland Orthomosaics Using GIS, Computer Vision, Computational Topology and Deep Learning

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Abstract: Invasive blueberry species endanger the sensitive environment of wetlands and protection laws call for management measures. Therefore, methods are needed to identify blueberry bushes, locate them, and characterise their distribution and properties with a minimum of disturbance. UAVs (Unmanned Aerial Vehicles) and image analysis have become important tools for classification and detection approaches. In this study, techniques, such as GIS (Geographical Information Systems) and deep learning, were combined in order to detect invasive blueberry species in wetland environments. Images that were collected by UAV were used to produce orthomosaics, which were analysed to produce maps of blueberry location, distribution, and spread in each study site, as well as bush height and area information. Deep learning networks were used with transfer learning and unfrozen weights in order to automatically detect blueberry bushes reaching True Positive Values (TPV) of 93.83% and an Overall Accuracy (OA) of 98.83%. A refinement of the result masks reached a Dice of 0.624. This study provides an efficient and effective methodology to study wetlands while using different techniques.

Keywords: ArcGIS; big data; blueberries; deep learning; image analysis; orthomosaics; segmentation refinement; UAVs

Citation: Kentsch, S.; Cabezas, M.; Tomhave, L.; Groß, J.; Burkhard, B.; Lopez Caceres, M.L.; Waki, K.; Diez, Y. Analysis of UAV-Acquired Wetland Orthomosaics Using GIS, Computer Vision, Computational Topology and Deep Learning. *Sensors* **2021**, *21*, 471. https://doi.org/10.3390/s21020471

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Accepted: 7 January 2021
Published: 11 January 2021

1. Introduction

Recent changes in global climate conditions influence species composition and accelerating the presence of invasive plant species in natural environments. Species that spread outside their native habitat and rapidly and effectively adapt to new environments are known as invasive species [1]. The spread of invasive species often benefits from ecosystem changes and habitat disturbances that weaken the natural species and open an ecological niche for invaders. Hence, invasive species can influence the biodiversity, thus limiting the growth of natural plant species due to a higher occurrence of an invasive species, which could lead to ecosystem degradation [2]. The fast adaption to multiple stress factors in environments could also lead to a replacement of native species and it may increase economic costs due to production losses in agriculture and forestry [3]. In Europe, 11% of the 12,000 identified species have caused damage to the economy, society, and the environment [4]. Reference [5] states that hundreds of invasive species find their pathways through horticulture, agriculture, etc., and the linearly increasing trend of invasive species numbers (from 1970 to 2007) indicates higher impacts of invasive species in the future. Reference [6] pointed out that not only invasive species have an impact on native plants, since several factors often interact with the environment that influence species distributions. In recent years, the need to precisely understand the ecological impacts of invasive

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water

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Article

Modeling Residential Water Consumption in Amman: The Role of Intermittency, Storage, and Pricing for Piped and Tanker Water

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Abstract: Jordan faces an archetypal combination of high water scarcity, with a per capita water availability of around 150 m^3 per year significantly below the absolute scarcity threshold of 500 m^3, and strong population growth, especially due to the Syrian refugee crisis. A transition to more sustainable water consumption patterns will likely require Jordan's water authorities to rely more strongly on water demand management in the future. We conduct a case study of the effects of pricing policies, using an agent-based model of household water consumption in Jordan's capital Amman, in order to analyze the distribution of burdens imposed by demand-side policies across society. Amman's households face highly intermittent piped water supply, leading them to supplement it with water from storage tanks and informal private tanker operators. Using a detailed data set of the distribution of supply durations across Amman, our model can derive the demand for additional tanker water. We find that integrating these different supply sources into our model causes demand-side policies to have strongly heterogeneous effects across districts and income groups. This highlights the importance of a disaggregated perspective on water policy impacts in order to identify and potentially mitigate excessive burdens.

energies

MDPI

Article

A GIS-Based Method for Identification of Wide Area Rooftop Suitability for Minimum Size PV Systems Using LiDAR Data and Photogrammetry

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Abstract: Knowledge of roof geometry and physical features is essential for evaluation of the impact of multiple rooftop solar photovoltaic (PV) system installations on local electricity networks. The paper starts by listing current methods used and stating their strengths and weaknesses. No current method is capable of delivering accurate results with publicly available input data. Hence a different approach is developed, based on slope and aspect using aircraft-based Light Detection and Ranging (LiDAR) data, building footprint data, GIS (Geographical Information Systems) tools, and aerial photographs. It assesses each roof's suitability for PV deployment. That is, the characteristics of each roof are examined for fitting of at least a minimum size solar power system. In this way the minimum potential solar yield for region or city may be obtained. Accuracy is determined by ground-truthing against a database of 886 household systems. This is the largest validation of a rooftop assessment method to date. The method is flexible with few prior assumptions. It can generate data for various PV scenarios and future analyses.

Keywords: solar; LiDAR; rooftop photovoltaics; building characteristics; wide-area solar yield

1. Introduction

Solar energy has a vital role to play in the sustainable energy mix for achieving the 2020 deadline of the Paris Agreement [1]. This requires all cities to increase the supply of green energy and change consumption patterns. Knowledge of quantity and output timing of solar energy becomes increasingly important. It can help with managing self-consumption, pay-back times, profitability, carbon trading, and financial attractiveness of domestic PV systems [2]. There is some evidence that PV has less impact on the environment than other renewable technologies e.g., solar thermal [3], although use of flat plate collectors has reduced CO_2 emissions in Greece [4]. Efficiency of PV systems and their simulation are improving [5].

Exact calculation of the solar exposure on pitched roofs is essential for modelling photovoltaic (PV) deployment in domestic scenarios. Two popular tools for calculating in-plane radiation and PV energy production are PVGIS (Photovoltaic Geographical Information System) [6] and PVWatts Calculator [7]. These are free, web-based, do not require installation, and are based on minimal inputs. In order to produce results, these tools either require the user to enter system tilts and azimuths, or

International Journal of Geo-Information

MDPI

Article

Implementation of Web Map Services for Old Cadastral Maps

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Abstract: It is widely accepted that old cadastral maps have multiple uses, such as reestablishing cadastral parcel boundaries, municipality boundaries, and coastal limits, or conducting historical, economic, and social studies. In Spain, the Directorate General for Cadastre, and the National Geographic Institute, has numerous digitized old maps that are accessible to users. In the Comunidad Valenciana, the georeferencing of certain series of old cadastral maps is being carried out in phases, which is one of the subjects of this study. A metric analysis of two series of old cadastral maps from a municipality was conducted. One of the series was georeferenced by the Valencia Provincial Cadastre Office, while the other was georeferenced in this research. Additionally, a spatial data infrastructure (SDI) was created, providing WMS, catalog, and document download services. Metadata were also published, containing information about the source, digitalization process, georeferencing, and achieved accuracy, following the ISO 19115 standard for geographic metadata. Furthermore, through individual and group interviews, participatory social research was conducted, to assess the use of old cadastral maps and the created SDI services, aiming to understand the users' appreciation of the services. The results of the social research indicate that the SDI services created are highly valued, but certain conditions need to be met to ensure their effective use by the general public in order to avoid misuses and misinterpretations.

Keywords: cadastre; old maps; metadata; georeferencing; WMS; SDI; social research

Citation: Verdu-Candela, A.; Femenia-Ribera, C.; Mora-Navarro, G.; Sierra-Requena, R. Implementation of Web Map Services for Old Cadastral Maps. *ISPRS Int. J. Geo-Inf.* **2023**, *12*, 413. https://doi.org/10.3390/ijgi12100413

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1. Introduction

Cadastral maps are generally an essential part of territory management, serving different purposes depending on their characteristics [1]. In Spain, cadastral data are primarily created for calculating taxes. Properties' maps, uses, owners, and values are recorded. The main objective of Spanish cadastral cartography is fiscal, although it also delimits geographic elements such as settlements, buildings, urban furniture, place names, administrative boundaries [2], addresses, and public domain features (hydrography, transport infrastructure, protected areas). The purpose of including these additional cartographic elements is to provide context to the properties within their surroundings. Thanks to these cartographic elements, current cadastral maps are widely used as a source for many studies, including geomarketing [3,4], analysis of urban development [5,6] and optimizing access to urban facilities [7]. Many of these studies are made possible because cadastral maps allow for georeferencing other data through the national cadastral reference.

In Spain, the competent authority responsible for managing the cadastral maps of most Spanish territory is the Spanish Directorate General for Cadastre (DGC). Cadastral maps are freely available through the Electronic Office of Cadastre (EOC).

Old cadastral maps (OCMs) also have numerous applications, such as land use reconstruction [8,9], agricultural studies [10], mining [11], archaeological research [12], cadastral plot stakeout [13,14], and historical demographic and social studies [15,16].

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Palmer, D., Koumpli, E., Cole, I. et al. (2018). A GIS-Based Method for Identification of Wide Area Rooftop Suitability for Minimum Size PV Systems Using LiDAR Data and Photogrammetry. Energies. [Online]. 11 (12). p.p. 3506. http://dx.doi.org/10.3390/en11123506

Verdu-Candela, A., Femenia-Ribera, C., Mora-Navarro, G. y Sierra-Requena, R. (2023). Implementation of Web Map Services for Old Cadastral Maps. ISPRS International Journal of Geo-Information. [Online]. 12 (10). p.p. 413. http://dx.doi.org/10.3390/ijgi12100413

C.3. SNAP

CG9. C3

1. Descripción

SNAP (Sentinel Application Platform), es una arquitectura común para todas las Sentinel Toolboxes, desarrollada conjuntamente por Brockmann Consult, SkyWatch y C-S.

SNAP es la plataforma de software común para las tres Toolboxes (Sentinel-1, Sentinel-2, Sentinel-3, SMOS y PROBA-V) desarrolladas por la Agencia Espacial Europea (ESA) para la explotación científica de misiones ópticas y de microondas.

La arquitectura SNAP es ideal para el procesamiento y análisis de la observación de la Tierra debido a las siguientes innovaciones tecnológicas: extensibilidad, portabilidad, plataforma modular de cliente enriquecido, abstracción de datos EO genéricos, gestión de memoria en mosaico y un marco de procesamiento de gráficos.

Las Toolboes de la ESA apoyan la explotación científica de las misiones ERS-ENVISAT, las misiones Sentinels 1/2/3 y una variedad de misiones nacionales y de terceros. Las tres Toolboxes se denominan respectivamente Sentinel 1, 2 y 3 y comparten una arquitectura común llamada SNAP. Contienen algunas funcionalidades de las Toolboxes históricas como BEAM, NEST y Orfeo Toolbox que se desarrollaron durante los últimos años.

Este software se ha usado recientemente en los trabajos de Gomarasca et al., 2019; Kokhanovsky et al., 2018; Hilmi Erkoç, 2023; Lateh et al., 2020; Pasqualotto et al., 2019; Van der Woerd, et al., 2016 y Tan, 2023.

2. Características técnicas

Programa	SNAP - SeNtinel's Application Platform		
Versión	9.0.6	Año	2022
Tipología	Teledetección		
Capacidades del programa	SNAP (Sentinel Application Platform) es una arquitectura común de código abierto para Toolboxes de ESA (Agencia Espacial Europea) ideal para la explotación de la observación de la Tierra. La arquitectura SNAP es ideal para el procesamiento y análisis de la observación de la Tierra debido a las siguientes innovaciones tecnológicas: extensibilidad, portabilidad, plataforma de cliente enriquecido modular, abstracción de datos EO genéricos, administración de memoria en mosaico y un marco de procesamiento de gráficos.		
Sistema operativo	Unix (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits y arm M1)		
Tipo de sistema (arquitectura)	64 bits arm M1	Tipo de licencia	Código Abierto licenciado bajo GNU/GPL (General Public License)
Desarrollador	Brockmann Consult - SkyWatch - C-S		
Web	https://step.esa.int/main/toolboxes/snap/		

3. Ejemplos de trabajos científicos

Copernicus Sentinel missions for Water Resources

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C. Sandu
ITHACA
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F. Giulio Tonolo
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Abstract— **The European Union and the European Space Agency (EU/ESA) have promoted since 1998 (Baveno Manifesto*) the GMES Programme (Global Monitoring for Environment and Security), nowadays called Copernicus (www.copernicus.eu).**
In the water quality domain, the use of Copernicus Sentinel missions and services improvements occur studying chlorophyll-a (Chl-a) concentrations, phycocyanin (PC), total suspended matter (TSM), colored dissolved organic matter (CDOM) and water surface temperature, with attention to the Cost/Benefit analysis (environmental and economic). The fundamentals of Earth Observation (EO), Geographic Information (GI) and Geomatics techniques, are crucial for the development of innovative strategies for professional skills adequacy and capacity building [1], supporting Copernicus user uptake.
One of the main goal is to help bridging gaps between supply and demand in terms of education and training for the geospatial sector, reinforcing the existing academic proposal, fostering the uptake and the integration of Copernicus geospatial data and services in end-user applications (www.eo4geo.eu).
Referring to the water resources domain, topics to be included in Summer Schools training course are: atmospheric correction, optical properties, algorithms to retrieve water quality information. The outcomes of several concluded or ongoing international projects (H2020 EOMORES, Earth Observation based services for Monitoring and Reporting of Ecological Status, and ESA - SEOM SEN2CORAL) should be also taken into account, being aimed at developing commercial services for monitoring the quality of inland and coastal water bodies and to improve processing algorithms. Such activities are supported by innovative and strategical novelties like the complete free access to the imagery archives of the Copernicus Sentinel missions and the availability of the dedicated data processing software SNAP (SeNtinel Application Platform). Additionally, cloud-based solution embedding global archive catalogues (e.g. Google Earth Engine) enables planetary-scale geospatial analyses, allowing real world scenarios to be operationally tackled.

Keywords-component; Copernicus; Sentinel; Water Resources; Earth Observation; Geomatics

I. INTRODUCTION

The Copernicus Programme, the EU Earth Observation and monitoring programme, was established by Regulation (EU) No 377/2014, European Parliament and Council, April 3rd, 2014 (http://www.copernicus.eu/). It was designed to provide a European response to Global needs such as the environment management, climate change effects mitigation and to ensure civil and citizen security. The Programme entered its operational phase with the launch of Sentinel-1A in 2014 and its governance is based on the Copernicus Regulation adopted the same year witch established the Commission as the Programme manager owing the infrastructure and data rights on behalf of the Union. The Space segment and services are based on information from a dedicated constellation of satellites (Sentinels), as well as of the third-party satellites known as *contributing space missions*, complemented by *in situ* (meaning local or on site) measurement data and the added value products.

The Copernicus Sentinel missions are six, namely: Sentinel-1 provides all-weather, day and night radar imagery for land and ocean services, Sentinel-2 provides high-resolution optical imagery for land services, Sentinel-3 provides high-accuracy optical, radar and altimetry data for marine and land services, Sentinel-4 and Senitnel-5 will provide data for atmospheric composition monitoring, Sentinel-5 Precursor is a gap filler mission aiming to provide data continuity until the launch of Sentinel-5, Sentinel-6 will provide high accuracy altimetry for measuring global sea-surface height. Sentinel 1, 2, 3, 5P and 6 are dedicated satellites, while Sentinel-4 and 5 are instruments onboard EUMETSAT's weather satellites (https://sentinel.esa.int).

The Copernicus Open Access Hub (https://scihub.copernicus.eu, previously known as Sentinels Scientific Data Hub) provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products,

Copernicus contribute towards the development of new innovative applications and services, tailored to the need of specific groups of user. The fundamental pillars of the Programme are the six cross cutting thematic services: Land monitoring, Marine environment, Atmosphere, Climate Change, Emergency Management and Security. The engagement of Member States takes place in the frame of the National User Forum, and is characterized by some common denominators: coping with the European and national obligations, facilitating and sustaining the scientific and technologic innovation to realize downstream services and societal benefits through the National Space Economy and

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Snow Processor for Sentinel Application Platform: underlying algorithm and its validation

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The Sentinel Application Platform (SNAP) architecture is ideal for Earth Observation processing and analysis (http://step.esa.int/main/toolboxes/snap/). In this work we develop a new Snow Processor and respective plugin for SNAP. We also describe physical principles behind the developed snow property retrieval technique based on the analysis of Ocean and Land Colour Instrument (OLCI) onboard Sentinel-3A/B measurements over fresh and polluted snow fields. Using OLCI spectral reflectance measurements in the range 400-1020nm, we derive such important snow properties as albedo (spectral and broadband), snow specific area, snow extent and snow grain size on the spatial grid of 300m. The algorithm also incorporates cloud screening and atmospheric correction procedures over bright snow surfaces.

The results of validation of the retrieved snow products using ground measurements performed in Antarctica and also on Greenland Ice Sheet are given. In particular, we have found that the spectral albedo is retrieved with accuracy of about 2-3% sufficient for climatic studies and also for other applications. The broadband albedo is retrieved with the accuracy of about 5% over fresh snow fields. The retrieved grain size based on the OLCI measurements at the wavelengths 865 and 1020nm has been compared with the snow grain size measurements performed on ground. The agreement is not such good as for albedo because of a priori assumptions implemented in the retrieval algorithm and also due to uncertainty in the grain size definition for irregularly shaped ice crystals in snow and its spatial variability. It is difficult to maintain the same standards of grain size measurements in the field. On the other hand, the derived optical snow grain size from OLCI measurements is obtained in the framework of the same theoretical formulation and consistent with derived albedo values. Therefore, it can be considered as an essential climate variable linked both to spectral and broadband snow albedos.

We also show the examples of snow albedo/grain size mapping over extended areas of Antarctica and Greenland using SNAP and OLCI measurements on board Sentinel-3A/B. The algorithm can be applied to upcoming OLCI Sentinel-3C/D measurements providing an opportunity for creation of long – term snow property records essential for climate change studies - especially in the Arctic region, where we face rapid environmental changes including reduction of snow/ice extent and, therefore, planetary albedo.

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Examination of Causes for Decrease in the Water Level of Beysehir Lake and Shrinkage in the Lake's Surface Area.

Muharrem Hilmi Erkoç

This study investigates the reasons for the decrease in the water level of Beysehir Lake and the shrinkage in the lake's surface area in recent years. For this purpose, the lake water level was determined from multi-mission satellite altimeter data, and the lake area was calculated using high-resolution optical satellite images. Data from Copernicus Global Land Service was used for multi-mission satellite altimeter data, and the lake level trend between 1993-2022 was calculated with the least squares method. European Space Agency's (ESA) Sentinel-2 high-resolution optical images were used to determine the change in the lake surface area between 2015 and 2020. These high-resolution optical images were processed with The Sentinel Application Platform (SNAP) software. The Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were calculated based on processed optical images, and these indexes reflect the changes in water surface area. From the satellite altimeter data, a decreasing trend of 2.5 ± 0.5 cm/yr in the lake water level in the last ten years and shrinkage of approximately 8 km^2 in the last 6 years from the satellite images were determined. The possibility of one of the most important reasons being drought was emphasized, and monthly average air temperature data and monthly average precipitation data were obtained from the Turkish General Directorate of Meteorology. With these data, 3- and 12-month Standardized Precipitation Evapotranspiration Index (SPEI) were calculated. Regarding these calculated drought indexes, moderate, extreme, and severe hydrological drought has been determined in the region. According to the analysis, drought is thought to be the most important reason for the decrease in the lake water level and shrinkage in the lake surface area.

Keywords : Geodesy for Climate, Lake Water Level, Satellite Altimetry, In-situ observation, Sentinel-2

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Application of interferometric SAR using Sentinel-1A for flood monitoring in South of Sulawesi, Indonesia

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Abstract. An updated information of flood mapping that recently occurred in South Sulawesi is an important necessity for site policy makers. Mapping of flood area during or soon after the flooding event is tremendous hardwork. However using active-remote sensing namely InSAR (Interferometric Synthetic Aperture Radar) technique can overcome these limitatations. To achieve it, at least two radar images have to be obtained which is 1 image before and 1 image during/after flood event. We selected 2 images Sentinel-1A GRD (Ground Range Detected) data for the same pass direction and the same time acquisitation with polarization VH (Vertical-Horizontal), 12 days of temporal baseline. The images were then processed by SNAP (Sentinel Application Platform) Toolbox. The results show that Sentinel-1A succeeded in detecting and monitoring flood event, where inundated of water in Tallo River is clearly visible in VH polarization.

1. Introduction

Recently, the flood had occurred on 25 January 2019 in South Sulawesi, Indonesia. The issue is necessary since there is a little information available about the site area. Since the study area is located in a tropical region, passive remote sensing displays certain limitations mainly cloud cover over the study area and data can only be acquired during the day, while on the other hand, active remote sensing, Synthetic Aperture Radar (SAR) can overcome these restrictions due to the data that can be acquired potentially at any time even day or night and even penetrates cloud cover. However, using active remote sensing such as Sentinel-1A is value added since its low revisit time 12 days and it is value added for flood monitoring.

Some examples of successful application of radar for flood monitoring [1], [2]. Mapping disaster map, when flood is still occuring is another positive output of using remote sensing.

1.1. Study Area

The study area is along the Tallo River to the Bili-Bili Dam located in Southern of Ujung Pandang City, Makasar, South Sulawesi (Figure 1 and Figure 3.a). For the investigated flood area and damage analysis, the Sentinel-1A (C-Band) SAR data with Ground Range Detected (GRD) product format were used. The mode of satellite data is Interferometric Wide (IW) which has swath width area of 250

agronomy

MDPI

Article

Retrieval of Evapotranspiration from Sentinel-2: Comparison of Vegetation Indices, Semi-Empirical Models and SNAP Biophysical Processor Approach

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Abstract: Remote sensing evapotranspiration estimation over agricultural areas is increasingly used for irrigation management during the crop growing cycle. Different methodologies based on remote sensing have emerged for the leaf area index (LAI) and the canopy chlorophyll content (CCC) estimation, essential biophysical parameters for crop evapotranspiration monitoring. Using Sentinel-2 (S2) spectral information, this study performed a comparative analysis of empirical (vegetation indices), semi-empirical (CLAIR model with fixed and calibrated extinction coefficient) and artificial neural network S2 products derived from the Sentinel Application Platform Software (SNAP) biophysical processor (ANN S2 products) approaches for the estimation of LAI and CCC. Four independent in situ collected datasets of LAI and CCC, obtained with standard instruments (LAI-2000, SPAD) and a smartphone application (PocketLAI), were used. The ANN S2 products present good statistics for LAI ($R^2 > 0.70$, root mean square error (RMSE) < 0.86) and CCC ($R^2 > 0.75$, RMSE < 0.68 g/m^2) retrievals. The normalized Sentinel-2 LAI index (SeLI) is the index that presents good statistics in each dataset ($R^2 > 0.71$, RMSE < 0.78) and for the CCC, the ratio red-edge chlorophyll index ($CI_{red\text{-}edge}$) ($R^2 > 0.67$, RMSE < 0.62 g/m^2). Both indices use bands located in the red-edge zone, highlighting the importance of this region. The LAI CLAIR model with a fixed extinction coefficient value produces a $R^2 > 0.63$ and a RMSE < 1.47 and calibrating this coefficient for each study area only improves the statistics in two areas (RMSE ≈ 0.70). Finally, this study analyzed the influence of the LAI parameter estimated with the different methodologies in the calculation of crop potential evapotranspiration (ET_c) with the adapted Penman–Monteith (FAO-56 PM), using a multi-temporal dataset. The results were compared with ET_c estimated as the product of the reference evapotranspiration (ET_o) and on the crop coefficient (K_c) derived from FAO table values. In the absence of independent reference ET data, the estimated ET_c with the LAI in situ values were considered as the proxy of the ground-truth. ET_c estimated with the ANN S2 LAI product is the closest to the ET_c values calculated with the LAI in situ ($R^2 > 0.90$, RMSE < 0.41 mm/d). Our findings indicate the good validation of ANN S2 LAI and CCC products and their further suitability for the implementation in evapotranspiration retrieval of agricultural areas.

Keywords: evapotranspiration in standard condition; leaf area index; canopy chlorophyll content; Sentinel-2; vegetation indices; artificial neural network

True color analysis of natural waters with SeaWiFS, MODIS, MERIS and OLCI by SNAP

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Abstract

The colors from natural waters differ markedly over the globe, depending on the water composition and illumination conditions. Space-borne "ocean color" sensors are operational instruments designed to retrieve important water-quality indicators, based on the measurement of water leaving radiance in a limited number (5 to 10) of narrow (≈10 nm) bands. Surprisingly, the analysis of the satellite data has not yet paid attention to color as an integral optical property that can also be retrieved from such multispectral satellite data. Based on a paper in Sensors [Van der Woerd and Wernand, 2015] we demonstrate that color, expressed mainly by the hue angle (α), can be derived accurate and consistently from SeaWiFS, MODIS, MERIS and OLCI data. The algorithm consists of a weighted linear sum of the remote sensing reflectance in all visual bands plus a correction term for the specific band-setting of each instrument. The algorithm is validated by a set of hyperspectral measurements from inland-, coastal- and near-ocean waters and makes a natural connection to hyperspectral measurements, smart phone measurements and the historic color observation of the 20th century. The algorithm is now available for these four instruments in the Sentinel-3 Toolbox, which is built on the Sentinel Application Platform (SNAP). We will present a number of SNAP-based applications that demonstrate that (α) is a parameter that adds new insight to ocean-color images.

Introduction

Color is a concept that originates in the human perception of radiation between the wavelengths of 380 to 720 nm. The human eye has three cone receptors that are very sensitive in the red, green or blue. Since the start of the 20th century the sensitivity of human color perception was well documented [CIE, 1932]. Also scientists like Forel and Ule found a way for a consistent measure of 'the water color' by using human perception to compare colors of natural waters. This Forel-Ule (FU) scale is a historical standard that has recently been very well calibrated [Novoa et al., 2013]. The scale was developed because of technological limitations that existed at the end of the 19th century. However, new initiatives in participatory science like within the EU-Citclops project, indicate that the color-comparison methodology can be transferred to nowadays measuring techniques using smart

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A New ground open water detection scheme using Sentinel-1 SAR images

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ABSTRACT

The detection of groundwater is essential not only for scientific research but also for agricultural purposes. This research aims to improve the accuracy and reliability of detecting ground standing water in cropland during the spring/early summer season in eastern South Dakota, USA, by reducing misclassification between water and vegetation. The study utilizes Sentinel-1 synthetic aperture radar (SAR) data. We selected and surveyed 159 ground sites, comprising 78 water sites and 81 nonwater sites, located between Brookings and Sioux Falls, SD, USA. The proposed scheme consists of three steps: 1) developing a modified speckle filter to reduce speckle noise while preserving image details, 2) characterizing the data for water and nonwater sites and providing parameter estimation using the Method of log-cumulants (MoLC) with generalized Gamma distribution (GΓD), and 3) applying Markov random field (MRF) for SAR data classification. The developed scheme demonstrates good performance with a site-based overall detection accuracy of 93.7%. In addition, it provides a computationally efficient solution for water detection, which can be applied in various applications such as crop insurance, precision agriculture and drought monitoring.

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KEYWORDS
Microwave remote sensing; SAR data; speckle filter; ground water detection; image classification; generalized Gamma distribution(GΓD)

Introduction

The detection of groundwater is not only of great interest to the scientific community but also to the industrial and agricultural communities. As global climate change becomes more widespread and intense, frequent and severe drought events are being observed worldwide (Intergovernmental Panel on Climate Change, https://www.ipcc.ch/report/ar6/wg1/#TS). For instance, the current drought in the western US has reached historic levels, and the situation has not improved. Nevertheless, groundwater and soil moisture detection can help assess the drought situation.

In addition, detecting groundwater in cropland helps yield estimation. The lack of water negatively impacts crop growth, leading to lower yields. However, excessive water can cause soil erosion, which also reduces crop productivity. To make matters worse, water runoffs carry fertilizers, herbicides, and insecticides from agricultural lands, which are then deposited into lakes, rivers, wetlands, and coastal waters, affecting both freshwater and marine ecosystems. Consequently, eutrophication has become a major environmental and economic problem (Dodds et al., 2009).

Furthermore, standing water in cropland may prevent the farmers from planting their crops in the spring, resulting in economic loss. This is especially true in the Northern Plains of the United States, where the planting window is relatively short. If the farmers miss the planting season due to standing water, they may not be able to plant later in the same year as the growing season is short. Hence, detecting groundwater is also crucial for crop insurance purpose.

There are several methods for groundwater detection, one of which is on-site mapping. However, due to the high labour cost, this method is not preferable. Other approaches use satellite remote sensing, which can provide data on a large area at a lower cost. Groundwater can be detected using a variety of satellite-based remote sensing techniques, including multispectral and hyperspectral sensors. Optical imaging sensors are typically used to take advantage of the water spectral reflectivity (Li et al., 2022; McFeeters, 1996; Wang et al., 2015; Xu, 2006). While optical sensors have been effective for various groundwater detection scenarios, there are notable limitations. Apart from the fact that optical sensors cannot work at night, they are also heavily weather-dependent, as cloud cover, rain, snow, fog, and smoke can block the satellite's view. Additionally, sun glint can also impact water detection (Brisco et al., 2009). In eastern South Dakota, rain and thunderstorms are frequent during spring and early summer. When it is not raining, there are often many cloudy days. Therefore, the regional weather condition prevents the optical imaging sensors from providing timely updates on ground conditions.

A synthetic aperture radar (SAR) approach, which works virtually under all weather conditions, during day and night, is preferred in this case. Much research has been done on groundwater detection

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D. ESTADÍSTICA Y GEOESTADÍSTICA

D.1. R

CG9. D1

1. Descripción

R es un entorno y un lenguaje de programación con un enfoque estadístico. Se trata de un software libre, siendo uno de los programas más utilizados en investigación por la comunidad estadística, siendo muy popular en distintos ámbitos de las ciencias exactas, naturales y médicas. A esto contribuye la posibilidad de cargar en este programa diferentes bibliotecas o paquetes de funcionalidades de cálculo y gráficas.

R proporciona un amplio abanico de herramientas estadísticas: modelos lineales y no lineales, test estadísticos, análisis de series temporales, algoritmos de clasificación y agrupamiento, etc. Al igual que el lenguaje en el que se inspiró: *S*, el software R permite que los usuarios lo extiendan definiendo ellos mismos sus propias funciones dependiendo de sus requerimientos.

Existe una gran cantidad de extensiones y paquetes asociados a este programa y lenguaje de programación gracias a que forma parte de un proyecto colaborativo y abierto. En la actualidad existirán alrededor de 3.000 extensiones de R y su interoperabilidad es cada día mayor con otros programas informáticos.

Este software apareció en 1993, desarrollado por Ross Ihaka y Robert Gentleman del Departamento de Estadística de la Universidad de Auckland. Actualmente R es parte del sistema GNU y está disponible para los principales sistemas operativos del mercado, siendo la responsabilidad de sus modificaciones del R Development Core Team.

Este software se ha usado recientemente en los trabajos de Buchsteiner et al., 2023; Cao y Wang, 2023; Faybishenko, 2023; Papacharalampous et al., 2023; Siriwardhana et al., 2023 Umar y Gray, 2023 y Wagner et al., 2023.

2. Características técnicas

Programa	R		
Versión	4.3.2	Año	2023
Tipología	Estadística, Geoestadística		
Capacidades del programa	R es un lenguaje y entorno de computación y creación de gráficos estadísticos. Proporciona una amplia variedad de técnicas estadísticas (modelado lineal y no lineal, pruebas estadísticas clásicas, análisis de series temporales, clasificación, agrupamiento…) y gráficos de distinta naturaleza. Se puede extender la aplicación mediante *packages*, para poder trabajar con mapas y geoestadística.		
Sistema operativo	Unix (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits y arm M1 y M2)		
Tipo de sistema (arquitectura)	64 bits arm M1 y M2	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	The R Project for Statistical Computing		
Web	https://www.r-project.org/		

3. Ejemplos de trabajos científicos

remote sensing

MDPI

Article

Spatial Analysis of Intra-Annual Reed Ecosystem Dynamics at Lake Neusiedl Using RGB Drone Imagery and Deep Learning

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Abstract: The reed belt of Lake Neusiedl, covering half the size of the lake, is subject to massive changes due to the strong decline of the water level over the last several years, especially in 2021. In this study, we investigated the spatial and temporal variations within a long-term ecosystem research (LTER) site in a reed ecosystem at Lake Neusiedl in Austria under intense drought conditions. Spatio-temporal data sets from May to November 2021 were produced to analyze and detect changes in the wetland ecosystem over a single vegetation period. High-resolution orthomosaics processed from RGB imagery taken with an unmanned aerial vehicle (UAV) served as the basis for land cover classification and phenological analysis. An image annotation workflow was developed, and deep learning techniques using semantic image segmentation were applied to map land cover changes. The trained models delivered highly favorable results in terms of the assessed performance metrics. When considering the region between their minima and maxima, the water surface area decreased by 26.9%, the sediment area increased by 23.1%, and the vegetation area increased successively by 10.1% over the investigation period. Phenocam data for lateral phenological monitoring of the vegetation development of *Phragmites australis* was directly compared with phenological analysis from aerial imagery. This study reveals the enormous dynamics of the reed ecosystem of Lake Neusiedl, and additionally confirms the importance of remote sensing via drone and the strengths of deep learning for wetland classification.

Keywords: Lake Neusiedl; reed; LTER; land cover classification; deep learning; DeepLabv3+; structure from motion; RGB; UAV; green chromatic coordinates

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1. Introduction

Wetlands are of immense importance as highly valuable ecosystems intertwined with human welfare. They fulfill an indispensable function in preserving biodiversity, purifying water, enhancing resilience against storm surges, sequestering carbon, regulating microclimates, and more [1]. Reed belts in particular have ecological importance as habitats for highly specialized species and as a buffer zone for lakes and rivers. They provide an indispensable habitat for waterfowl [2] and invertebrates. Reed shoots are a food source for herbivores, and in an aquatic setting reed stands provide a spawning ground and nursery for fish [3], prevent erosion, and stabilize the strength of the bank [4]. The reed belt of Lake Neusiedl is the second largest coherent reed ecosystem in Europe after the Danube Delta, and for nature conservation reasons it is a very important habitat for many protected bird species [5]. Lake Neusiedl is a long-term ecological research (LTER) site contributing to a pan-European research network seeking to better understand the structures and functions of ecosystems (https://lter-austria.at, accessed on 5 August 2023) [6]. Remote sensing imagery is required to spatially visualize and analyze such sites and understand the effects of global changes at the local scale [7].

water

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Review

How to Statistically Disentangle the Effects of Environmental Factors and Human Disturbances: A Review

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Abstract: Contemporary biological assemblage composition and biodiversity are often shaped by a range of natural environmental factors, human disturbances, and their interactions. It is critical to disentangle the effects of individual natural variables and human stressors in data analysis to support management decision-making. Many statistical approaches have been proposed and used to estimate the biological effects of individual predictors, which often correlated and interacted with one another. In this article, we review nine of those approaches in terms of their strengths, limitations, and related r packages. Among those are hierarchical partitioning, propensity score, the sum of AIC weights, structural equation modeling, and tree-based machine learning algorithms. As no approach is perfect, we offer two suggestions: (1) reducing the number of predictors as low as possible by carefully screening all candidate predictors based on biological and statistical considerations; (2) selecting two or more approaches based on the characteristics of the given dataset and specific research goals of a study, and using them in parallel or sequence. Our review could help ecologists to navigate through this challenging process.

Keywords: variance partitioning; variable-importance ranking; collinearity; variable interactions; bioassessment; land use impact; climate change

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1. Introduction

Natural environmental factors (e.g., climate and elevation) and human disturbances (e.g., land use, fine sediment, and mining) are often found to jointly affect species abundance and communities in survey-based studies. It is critical to identify the real effects of individual factors or groups of factors for understanding the environmental process and making management decisions. In a controlled experiment, the effect of different factors and their interactions can be estimated with a randomized block design [1,2]. However, such a design only can accommodate a small number of factors at relatively small scales of space and time. Most ecological processes operate at broad spatial and time scales, such as urbanization, agricultural practices, river damming, and climate changes, and are not possible to experiment with [3]. Ecological surveys and modeling based on field data are essential to infer or test hypothesized casual-effects relationships between environment and biological responses.

In practice, the statistical difficulty in disentangling the effects of individual environmental factors and human stressors mainly comes from two sources. First, different biotic and abiotic predictors often co-vary with one another in a given study. When the co-variation is linear, it is referred to as collinearity. When three or more predictors are linearly correlated with one another, it is referred to as multicollinearity. Collinearity occurs for a number of reasons, such as being different descriptors of the same ecological and physical process. For example, mean, max, and min monthly temperatures are often highly correlated because they all describe thermal regimes. Collinearity may also happen because

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Article

A Concept of Fuzzy Dual Permeability of Fractured Porous Media

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Abstract: The interpretation of the results of hydrogeological field observations and the modeling of fractured porous subsurface media is often conducted using dual-porosity and/or dual-permeability concepts. These concepts, however, do not consider the effects of spatial and temporal variations and uncertainties, or fuzziness, in the evaluation of the subsurface flow characteristics of fractured porous media. The goal of the paper is to introduce a concept of fuzzy dual permeability of fractured porous media based on the fuzzy system analysis of the results of ponded infiltration tests in fractured basalt. The author revisited the results of the tests conducted in areas close to the Idaho National Laboratory (INL), Idaho, USA: small-scale (approximately 0.5 m^2) ponded tests at the Hell's Half Acre site, mesoscale (56 m^2) ponded tests at the Box Canyon site, and a large-scale infiltration test (31,416 m^2) at the Radioactive Waste Management Complex at INL. Methods of fuzzy clustering and fuzzy regression were applied to describe the time-depth waterfront penetration and to characterize the phenomena of rapid flow through a predominantly fractured component and slow flow through a predominantly porous matrix component. The concept of fuzzy dual permeability is presented using a series of fuzzy membership functions of the waterfront propagation with depth and time. To describe the time variation of the flux, a fuzzy Horton's model is presented. The developed concept can be used for the uncertainty quantification in flow and transport in geologic media.

Keywords: ponded infiltration; fuzzy clustering; fuzzy regression; water travel time; fuzzy dual permeability; uncertainty; Horton's formula

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1. Introduction

Ponded infiltration tests are often conducted to investigate how land surface flooding events affect infiltration, groundwater recharge (e.g., [1,2]), and agricultural studies [3]. Multiple factors affect the infiltration into the subsurface, such as rough or rocky surface topography, subsurface media heterogeneity, soil swelling or shrinking, soil aggregation, and water and air redistribution within the porous space (e.g., [4,5]). Moreover, the flow processes take place at different temporal and spatial scales (e.g., [6,7]) through rock matrix pore structures as relatively "slow" flows and fracture networks as "fast" flows along localized preferential pathways. Therefore, the flow and transport in fractured rocks usually occur in a nonvolume-averaged fashion.

The modeling of nonvolume-averaged flow and transport processes in saturated–unsaturated fractured porous media is often conducted using macroscale continuum concepts, which are based on the application of the effective continuum, double porosity, dual permeability, or multiple interacting continua models (e.g., [8–11]). Contrary to the dual-porosity model that assumes stagnant water in the matrix, a dual-permeability model is based on the water exchange between the matrix and the fractures. However, such models may be inadequate for resolving spatially localized and nonrepeatable time-varying flow phenomena [12,13]. For example, a series of infiltration tests in fractured basalt demonstrated that the temporal trends of the infiltration rate are unrepeatable [14,15]. One of the reasons for the unrepeatability of the infiltration trend is the system's nonlinearity. Because

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Article

Comparison of Machine Learning Algorithms for Merging Gridded Satellite and Earth-Observed Precipitation Data

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Abstract: Gridded satellite precipitation datasets are useful in hydrological applications as they cover large regions with high density. However, they are not accurate in the sense that they do not agree with ground-based measurements. An established means for improving their accuracy is to correct them by adopting machine learning algorithms. This correction takes the form of a regression problem, in which the ground-based measurements have the role of the dependent variable and the satellite data are the predictor variables, together with topography factors (e.g., elevation). Most studies of this kind involve a limited number of machine learning algorithms and are conducted for a small region and for a limited time period. Thus, the results obtained through them are of local importance and do not provide more general guidance and best practices. To provide results that are generalizable and to contribute to the delivery of best practices, we here compare eight state-of-the-art machine learning algorithms in correcting satellite precipitation data for the entire contiguous United States and for a 15-year period. We use monthly data from the PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) gridded dataset, together with monthly earth-observed precipitation data from the Global Historical Climatology Network monthly database, version 2 (GHCNm). The results suggest that extreme gradient boosting (XGBoost) and random forests are the most accurate in terms of the squared error scoring function. The remaining algorithms can be ordered as follows, from the best to the worst: Bayesian regularized feed-forward neural networks, multivariate adaptive polynomial splines (poly-MARS), gradient boosting machines (gbm), multivariate adaptive regression splines (MARS), feed-forward neural networks and linear regression.

Keywords: benchmarking; big data; gradient boosting machines; PERSIANN; poly-MARS; random forests; remote sensing; satellite data correction; spatial interpolation; XGBoost

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1. Introduction

Knowing the quantity of precipitation at a dense spatial grid and for an extensive time period is important in solving a variety of hydrological engineering and science problems, including many of the major unsolved problems listed in Blöschl et al. [1]. The main sources of precipitation data are ground-based gauge networks and satellites [2]. Data from ground-based gauge networks are precise; however, maintaining such a network with a high spatial density and for a long time period is costly. On the other hand, satellite precipitation data are cheap to obtain but not accurate [3–6].

By merging gridded satellite precipitation products and ground-based measurements, we can obtain data that are more accurate than the raw satellite data and, simultaneously, cover space with a much higher density compared to the ground-based measurements. This merging is practically a regression problem in a spatial setting, with the satellite data being the predictor variables and the ground-based data being the dependent variables. Such kinds of problems are also commonly referred to under the term "downscaling" and are special types of spatial interpolation. The latter problem is met in a variety of fields

sustainability

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Article

A Simplified Equation for Calculating the Water Quality Index (WQI), Kalu River, Sri Lanka

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Abstract: The water supply system plays a major role in the community. The water source is carefully selected based on quality, quantity, and reliability. The quality of water at its sources is continuously deteriorating due to various anthropogenic activities and is a major concern to public health as well. The Kalu River is one of the major water resources in Sri Lanka that supplies potable water to the Kalutara district (a highly populated area) and Rathnapura district. But, there has been no significant research or investigation to examine anthropogenic activities in the river. Due to this, it is difficult to find any proper study related to the overall water quality in the Kalu River. Therefore, this study covers a crucial part related to the water quality of the Kalu River. The spatiotemporal variation of river water quality is highly important not only to processing any treatment activities but also to implementing policy decisions. In this context, water quality management is a global concern as countries strive to meet the United Nations Sustainable Development Goal 6, which aims to ensure the availability and sustainable management of water and sanitation for all. Poor water quality can have severe consequences on human health, ecosystems, and economies. Contaminated water sources pose risks of waterborne diseases, reduced agricultural productivity, and ecological imbalances. Hence, assessing and improving water quality is crucial for achieving sustainable development worldwide. Therefore, this paper presents a comprehensive analysis of spatiotemporal analysis of the water quality of the Kalu River using the water quality data of eight locations for 6 years from 2017 to 2023. Nine water quality parameters, including the pH, electrical conductivity, temperature, chemical oxygen demand, biological oxygen demand, total nitrate, total phosphate, total sulfate, total chlorine, and hardness, were used to develop a simple equation to investigate the water quality index (WQI) of the river. Higher WQI values were not recorded near the famous Kalutara Bridge throughout the years, even though the area is highly urbanized and toured due to religious importance. Overall, the water quality of the river can be considered acceptable based on the results of the WQI. The country lockdowns due to COVID-19 might have impacted the results in 2020; this can be clearly seen with the variation of the annual WQI average, as it clearly indicates decreased levels of the WQI in the years 2020 and 2021, and again, the rise of the WQI level in 2022, as this time period corresponds to the lockdown season and relaxation of the lockdown season in the country. Somehow, for most cases in the Kalu River, the WQI level is well below 25, which can be considered acceptable and suitable for human purposes. But, it may need some attention towards the areas to find possible reasons that

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water

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Article

Comparing Single and Multiple Imputation Approaches for Missing Values in Univariate and Multivariate Water Level Data

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Abstract: Missing values in water level data is a persistent problem in data modelling and especially common in developing countries. Data imputation has received considerable research attention, to raise the quality of data in the study of extreme events such as flooding and droughts. This article evaluates single and multiple imputation methods used on monthly univariate and multivariate water level data from four water stations on the rivers Benue and Niger in Nigeria. The missing completely at random, missing at random and missing not at random data mechanisms were each considered. The best imputation method is identified using two error metrics: root mean square error and mean absolute percentage error. For the univariate case, the seasonal decomposition method is best for imputing missing values at various missingness levels for all three missing mechanisms, followed by Kalman smoothing, while random imputation is much poorer. For instance, for 5% missing data for the Kainji water station, missing completely at random, the Kalman smoothing, random and seasonal decomposition methods had average root mean square errors of 13.61, 102.60 and 10.46, respectively. For the multivariate case, missForest is best, closely followed by k nearest neighbour for the missing completely at random and missing at random mechanisms, and k nearest neighbour is best, followed by missForest, for the missing not at random mechanism. The random forest and predictive mean matching methods perform poorly in terms of the two metrics considered. For example, for 10% missing data missing completely at random for the Ibi water station, the average root mean square errors for random forest, k nearest neighbour, missForest and predictive mean matching were 22.51, 17.17, 14.60 and 25.98, respectively. The results indicate that the seasonal decomposition method, and missForest or k nearest neighbour methods, can impute univariate and multivariate water level missing data, respectively, with higher accuracy than the other methods considered.

Keywords: data gaps; water level data; time series; univariate; multivariate; imputation

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1. Introduction

Water level is a measure of water depth in rivers/basin/lakes within a given place over time. Studying water level is important as it can provide warnings for flood risk, which helps to limit the impact of flood disasters on the local population and is also crucial for effective water resources management and for policy makers [1]. The study of water level is also important for the health of a river, to determine the required level for plants and animals to survive at various times of year [2].

Khalifeloo [3] states that recent extreme events globally, such as flooding, drought and bush burning, among other natural disasters, were caused largely by climate change, and these have attracted the attention of researchers to try to provide solutions. Accurate prediction of such extreme events can allow mitigating measures to be implemented. However, much water level/hydrological data is complicated by missing observations, especially in developing countries [4,5], which makes accurate prediction very difficult.

water

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Article

Edge-of-Field Runoff Analysis following Grazing and Silvicultural Best Management Practices in Northeast Texas

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Abstract: Landowners and natural resource agencies are seeking to better understand the benefits of best management practices (BMPs) for addressing water quality issues. Using edge-of-field and edge-of-farm runoff analysis, we compared runoff volumes and water quality between small watersheds where BMPs (e.g., prescribed grazing, silvicultural practices) were implemented and control watersheds managed using conventional practices (i.e., continuous grazing, natural forest revegetation). Flow-weighted samples, collected over a 2-year period using automated samplers, were analyzed for nitrate/nitrite nitrogen (NNN), total Kjeldahl nitrogen (TKN), total phosphorus (P), ortho-phosphate phosphorous (OP), total suspended solids (TSS), and *Escherichia coli* (*E. coli*). Comparison of silvicultural planting to conventional reforestation practices showed a significant decrease in NNN loads ($p < 0.05$) but no significant differences in TKN, P, OP, TSS, or *E. coli*. Continuously grazed sites yielded >24% more runoff than sites that were under prescribed grazing regimes, despite receiving less total rainfall. Likewise, NNN, TSS, and TKN loadings were significantly lower under prescribed grazing management than on conventionally grazed sites ($p < 0.05$). Data suggests that grazing BMPs can be an effective tool for rapidly improving water quality. However, silvicultural BMPs require more time (i.e., >2 years) to establish and achieve detectable improvements.

Keywords: conservation; sediment; nutrients; *E. coli*; non-point source; water quality

Citation: Wagner, K.L.; Gregory, L.; Gerlich, J.A.; Rhodes, E.C.; deVilleneuve, S. Edge-of-Field Runoff Analysis following Grazing and Silvicultural Best Management Practices in Northeast Texas. *Water* **2023**, *15*, 3537. https://doi.org/10.3390/w15203537

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1. Introduction

Despite decades of remediation efforts since the adoption of the Clean Water Act in the United States (US), nonpoint source (NPS) pollution remains a substantial challenge and contributor to surface water quality impairments [1–3]. NPS runoff is a major source of nutrient loading, leading to eutrophication and oxygen depletion in downstream waterbodies [3–5]. NPS runoff can also transport fecal indicator bacteria and pathogens, leading to recreational impairments [6]. Collectively, pathogens, nutrients, organic enrichment/oxygen depletion, and sediment/turbidity account for 49% of Clean Water Act Section 303(d) impairments in the US and 69% in the state of Texas [1,7].

Surface water quality has been shown to often be related to land use and land cover within a watershed [8–11]. Topsoil and nutrient losses can have detrimental effects on soil productivity, agricultural performance [12,13], economic gains [14], and water quality [15–17]. Additionally, the nonpoint source transport of fecal material and potential associated pathogens is a concern for recreational safety [18,19]. In many states like Texas, private agricultural and silvicultural working lands make up the vast majority of the total land area, providing for significant economic, environmental, and recreational applications [20]. Thus, it stands to reason that farmers, ranchers, and other agricultural producers (e.g., forestry operations) are most often looked to for conservation improvement projects to reduce nutrient, sediment, and bacterial NPS pollutant loadings from working lands [21].

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D.2. GNU PSPP

CG9. D2

1. Descripción

PSPP es una aplicación de software libre para el análisis de datos. Se presenta en modo gráfico y está escrita en el lenguaje de programación C. Usa la biblioteca científica GNU para sus rutinas matemáticas, y plotutils para la generación de gráficos. Es un reemplazo libre para el software propietario SPSS siendo muy parecido a éste con algunas excepciones como la no existencia de límites artificiales en la cantidad de casos o variables a estudiar.

Proporciona funcionalidades básicas como: estadísticas descriptivas, pruebas T, ANOVA, regresión lineal y logística, medidas de asociación, análisis de conglomerados, pruebas no paramétricas, etc.

frecuencias, tablas cruzadas, comparación de media, regresión lineal, fiabilidad, reordenamiento de datos, pruebas no paramétricas, factor de análisis entre otras características.

Los formatos de salida pueden ser: en ASCII, PDF, PostScript o HTML así como algunos gráficos estadísticos: histogramas, gráficos circulares y gráficos de distribución normal. PSPP puede importar formatos de: Gnumeric, OpenDocument, hojas de Excel , bases de datos Postgres, valores separados por coma y archivos ASCII. Puede exportar archivos en formato SPSS y archivos ASCII. Algunas de las bibliotecas usadas por PSPP pueden ser accedidas vía programación.

PSPP está desarrollado por la Free Software Foundation perteneciente a la GNU, se trata de un proyecto colaborativo de software libre con el objetivo de crear un sistema operativo completamente libre. La primera versión del programa fue lanzada en 1998.

Este software se ha usado recientemente en los trabajos de Antonova et al., 2023; Hossain et al., 2019; Mendoza et al., 2023; Sicoe et al., 2023; Tarasov et al., 2022 y Tortosa et al., 2018.

2. Características técnicas

Programa	GNU PSPP		
Versión	1.6.2	Año	2022
Tipología	Estadística		
Capacidades del programa	Herramienta para el análisis estadístico de datos. Este programa lee los datos, los analiza según los comandos previstos y escribe los resultados en un archivo de salida o mediante gráficos. El lenguaje aceptado por PSPP es similar a los aceptados por los productos estadísticos del software comercial SPSS. Puede realizar estadística descriptiva como T-tests, ANOVA, regresiones lineales y logísticas, medidas de asociación, análisis de clusters (conglomerados), pruebas no paramétricas, etc.		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU (General Public License)
Desarrollador	GNU Operating System, The Free Software Foundation (FSF)		
Web	https://www.gnu.org/software/pspp/		

3. Ejemplos de trabajos científicos

water

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Article

Determinants of Water Consumption in Hotels: New Insights Obtained through a Case Study

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Abstract: The literature on water use in hotels has identified numerous determinants of water consumption, but a consensus has yet to be reached on the influence of some of these factors. This article aims to enhance the current research framework on water use in the hotel sector by presenting a case study of one hotel in Tenerife, Canary Islands. The conceptual framework of water consumption in hotels is presented based on the previous literature. Starting from that, basic statistical analysis and bivariate correlations were performed on water consumption data from 2007 to 2019 to determine the significant factors affecting both total water consumption and consumption per guest night. Special attention was paid to water usage in gardens and the impact of weather conditions, as there is a lack of research focused on them. Additionally, the water management actions of the hotel were classified according to the business' themes proposed for the Sustainable Development Goals, using an internationally recognized guide, thus addressing one of the gaps identified in the literature. The results generally support previous research findings, but some discrepancies were noted regarding the number of guest nights and the effectiveness of implementing water-saving measures. This raises new questions about the characteristics of various water-saving measures, such as room renovation, and their influence on customer behavior, which may alter the intended impact on water consumption. Therefore, the findings of this study can provide an insight into unclear aspects in this area. They could also benefit hotels in terms of sustainability communication by allowing them to position their actions with an internationally recognized framework.

Keywords: tourism; hotel; water management; water consumption; water-saving measures; sustainable development goals

Citation: Antonova, N.; Mendoza-Jiménez, J.; Ruiz-Rosa, I. Determinants of Water Consumption in Hotels: New Insights Obtained through a Case Study. *Water* **2023**, *15*, 3049. https://doi.org/10.3390/w15173049

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1. Introduction

Water is a crucial topic on the sustainability agenda, with access to safe drinking water and sanitation recognized as human rights by the United Nations [1]. The accurate measurement of water use and availability has been an important aspect related to the Sustainable Development Goals (SDGs). The contribution of the private sector, including the tourism industry, to improve water management, seems to be more related to "aspects of strategic execution" [2] (p. 1), meaning that the ethic and/or social component is still missing in most of the cases. Nevertheless, implementing correct water management, with special focus on measurement, is not only a moral or legal obligation for businesses but it can result into added value for private organizations, as noted by [3].

In the tourism industry, water is one of the most strategic natural resources, and, within it, hotels are considered one of the main consumers of water [4–7]. However, the inefficient management of this resource can cause serious environmental problems, particularly in areas where water scarcity coexists with high demand [8–10]. Seeking ways to save water is essential, especially in geographical areas where water availability is limited, and tourism activities put pressure on water resources [11]. Therefore, a better knowledge on the factors

geosciences

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Article

Leaching Behavior of As, Pb, Ni, Fe, and Mn from Subsurface Marine and Nonmarine Depositional Environment in Central Kanto Plain, Japan

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Abstract: The leaching behavior of arsenic (As), lead (Pb), nickel (Ni), iron (Fe), and manganese (Mn) was investigated from subsurface core sediment of marine and nonmarine depositional environments in central Kanto Plain, Japan. A four-step sequential extraction technique was adopted to determine the chemical speciation, potential mobility, and bioavailability of metals under natural conditions in variable depositional environments. In addition, a correlation of these properties with pore water and total metal content was carried out. The concentration of As in pore water was found to be 2–3 times higher than the permissible limit (10 µg/L) for drinking water and leachate in fluvial, transitional, and marine environments. The trend of potential mobile fractions of As, Pb, and Ni showed Fe–Mn oxide bound > carbonate bound > ion exchangeable bound > water soluble in the fluvial environment. However, in the marine environment, it showed Fe–Mn oxide bound > water soluble > carbonate bound > ion exchangeable bound for As. The leaching of As in this fluvial environment is due to the organic matter-mediated, reductive dissolution of Fe–Mn oxide bound, where Mn is the scavenger. The amount of total content of As and sulfur (S) in transitional sediment reflects an elevated level of leachate in pore water, which is controlled by S reduction. However, the leaching of As in marine sediment is controlled by pH and organic matter content.

Keywords: marine and nonmarine sediments; hazardous trace metal; leaching behavior; sequential extraction

1. Introduction

Soil and sediment, which play a key role in geochemical cycling, are widely known as the sink and source of potentially hazardous trace metals [1]. Metals are bound with soil or sediment particles by a variety of mechanism with different metal phases. As a result, assessments of toxicity and bioavailability cannot be comprehensively undertaken by measuring only the total metal content [2]. It is important to perform specific speciation analyses. Sequential extraction analysis has become the most widely used method to determine precise chemical speciation, leaching behavior, and the potential mobility of metals in sediment [3–6]. It is also known as "operationally defined" when selected chemical reagents are used to extract metal from different phases or bindings of the soil/sediment particles [7–11].

As and Pb are recognized as highly toxic metalloids. These elements show persistent and toxic characteristics, even at very low concentrations, if they are ingested by humans and animals through air, water, or food intake [12]. There are many examples of the carcinogenic effects of As and Pb [13,14]. Groundwater is one of the main sources of drinking water due to freshwater scarcity and

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RESEARCH ARTICLE

Study of the hydraulic correlation in the removal of pollutants from synthetic wastewater by means of a filter with Musa Paradisiaca [version 1; peer review: 2 approved with reservations]

Benito Mendoza[1], Sandra Gabriela Barrazueta Rojas[2], Mayra Alejandra Pacheco Cunduri[2], María José Andrade Albán[2], Elvis Aucancela[3]

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Latest published: 13 Feb 2023, **12**:165
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Abstract

Background: The objective of this work was to decontaminate synthetic sewage from fouracid blue (BRL) dye, with characteristics similar to those of the textile industry, to determine the correlation between flow rate, permeability and removal of hexavalent chromium (Cr+ 6), Cupper (Cu), chemical oxygen demand COD and color using Paradise Muse filter bed.
Methods: three concentrations of BRL synthetic wastewater were prepared, determining the initial concentrations of Color, pH, COD, Cr +6 and Cu. In addition, the hydraulic characteristics of the fiber were determined in four types of fiber cut. The synthetic wastewater was filtered in a filtration cell with the three fiber cuts, using three speeds, the time used for these tests was 180 minutes. Water samples were collected every 5 minutes and then analyzed in the laboratory. Simple exponential smoothing was performed on the data obtained, and the statistical analysis of variance ANOVA of 2 factors.
Results: The results show that flow velocity and permeability are correlated with color removal, COD and Cr+ 6, determining that the best treatment was to use 1 cm fiber and high flow velocity in which 77.92% and 70.01% for color and COD respectively. In contrast, for Cr+ 6 the best treatment was fiber at 1 cm and low flow velocity removing up to 80% of the concentration of this contaminant and for Cu the best treatment was fiber at 3 cm and low flow velocity removing up to 88.69%.
Conclusions: It was determined that the Musa Pardisiaca fiber is capable of absorbing contaminants, but the effectiveness of the

Open Peer Review

Approval Status ? ?

	1	2
version 1 13 Feb 2023	? view	? view

1. **Sinan Kul**, Bayburt University, Bayburt, Turkey

2. **Rudolf Kiefer**, Ton Duc Thang University, Ho Chi Minh City, Vietnam

Any reports and responses or comments on the article can be found at the end of the article.

forests

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Article

Analysis of the Effects of Windthrows on the Microbiological Properties of the Forest Soils and Their Natural Regeneration

Silviu Ioan Sicoe [1], Ghiță Cristian Crainic [2], Alina Dora Samuel [3], Marinela Florica Bodog [2], Călin Ioan Iovan [2], Sorin Curilă [4], Ioan Ovidiu Hâruța [2], Eugenia Șerban [5], Lucian Sorin Dorog [2] and Nicu Cornel Sabău [5,*]

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Abstract: Windthrows in the forestry fund, which have become more frequent due to the increase in extreme weather events, have had, and continue to have, mostly negative economic and ecological effects, making them a pressing issue in forestry research. The main objectives of this study are to evaluate the effects of windthrows on some microbiological properties of forest soils and to monitor the evolution of the degraded tree regeneration, four years after the event, for three tree species: Norway spruce (*Picea abies* L.), sessile oak (*Quercus petraea*), and European beech (*Fagus sylvatica* L.). The experimental plot used is arranged in dispersed blocks and subdivided plots, with three repetitions, and is bifactorial, with factor A representing the tree species and factor B the windthrows. There are two possibilities: affected by windthrows (AW) and unaffected by windthrows (WW). For each tree species, dehydrogenase activity (DA) and the number of fungi (NF) in the organic horizon at the soil surface were studied. Correlations were highlighted between the differences in AW and WW of Current Dehydrogenase Activity (CDA), Potential Dehydrogenase Activity (PDA), and NF with the number of naturally regenerated seedlings (NRS) and the type of soil. Stimulating NRS in AW forests and increasing the volume of terrestrial organic carbon (TOC) biomass is directly dependent on soil fertility, primarily determined by Soil Organic Carbon (SOC), which accumulates in the soil as a result of organic matter, deposited on the surface. Sustainable forest management of AW plots should stimulate the accumulation of SOC, including the partial or total preservation of dead trees, provided that the attack of specific diseases and pests is avoided.

Keywords: windthrow; organic carbon; dehydrogenase activity; number of fungi; natural regeneration

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1. Introduction

Forest ecosystems are areas of the landscape dominated by trees and consisting of biologically integrated communities of plants, animals, and microorganisms, together with the soils and local atmosphere with which they interact [1]. Forest ecosystems represent a strategic natural biotic potential, which through their structural and functional diversity comprise the most valuable associations of natural vegetation. In addition to their production and protection functions, forests can also perform functions of mitigating current global climate change through the absorption and storage of greenhouse gases [2]. The functions of carbon storage and greenhouse gas mitigation [3] have become an international priority, as demonstrated by the Green Paper on "Preparing forests for climate change" [4].

applied sciences

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Article

The Effect of Pre-Treatment of Arabica Coffee Beans with Cold Atmospheric Plasma, Microwave Radiation, Slow and Fast Freezing on Antioxidant Activity of Aqueous Coffee Extract

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Abstract: Thermal and non-thermal technologies used in food processing should be not only effective in terms of decontamination and preservation but also minimize undesirable losses of natural bioactive compounds. Arabica (*Coffea arabica*) is the most cultivated variety of coffee, making it a valuable source of phytonutrients, including antioxidants. In the present study, green and roasted Arabica coffee beans were treated with slow freezing (SF), fast freezing (FF), microwave radiation (MWR) and cold atmospheric plasma (CAP). Moisture content (MC) of coffee beans and antioxidant activity (AOA) of aqueous extracts were measured. Green coffee showed a decrease in MC after MWR treatment, and roasted coffee showed an increase in MC after freezing. After SF and FF at −19 °C for 24 h, all extract samples showed an increase in AOA by 4.1–17.2%. MWR treatment at 800 W for 60 s was accompanied by an increase in the AOA of green coffee extracts by 5.7%, while the changes in the AOA of roasted coffee extracts were insignificant. Sequential combined treatments of SF + MWR and FF + MWR resulted in an additive/synergistic increase in the AOA of green/roasted coffee extracts, up to +23.0%. After CAP treatment with dielectric barrier discharge (DBD) parameters of 1 μs, 15 kV and 200 Hz for 5 and 15 min, green coffee showed a decrease in the extract AOA by 3.8% and 9.7%, respectively, while the changes in the AOA of roasted coffee extracts were insignificant. A high positive correlation ($r = 0.89$, $p < 0.001$) between AOA and MC was revealed. The results obtained indicate that SF, FF, MWR and combined treatments may be applied at the pre-extraction stage of coffee bean preparation in order to increase the yield of antioxidant extractives.

Keywords: coffee; Arabica; freezing; microwave; cold atmospheric plasma; antioxidant activity; moisture content; pre-extraction preparation; extraction yield

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1. Introduction

Coffee is one of the most popular soft drinks that are consumed by people of different age groups. Epidemiological and experimental studies showed that recommended intakes of three to five cups of coffee a day for adults might have a positive effect on the functionality of the human brain, respiratory, endocrine and digestive systems. Coffee consumption was also linked to a lower risk of developing several specific cancers. The side effects of coffee consumption, such as temporarily growth in blood pressure, insomnia, anxiety and the risk of miscarriage, were associated exclusively with high daily caffeine intakes (400 mg for adults and 200 mg for pregnant women) and, thus, were not relevant in case of decaffeinated drinks [1,2]. A recent study [3] involving 37,988 participants of the UK Biobank

agronomy

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Article

"Alperujo" Compost Improves the Ascorbate (Vitamin C) Content in Pepper (*Capsicum annuum* L.) Fruits and Influences Their Oxidative Metabolism

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Abstract: "Alperujo" compost was evaluated as an organic fertiliser for pepper growth under greenhouse conditions. Even though the total nitrogen applied was similar, plants only grown with composts experienced a development decline as compared to those grown with standard nutrient solution. This was perhaps because nitrogen from the compost was essentially organic, and not easily available for roots. When, alternatively, the compost was supplemented with nitrate, a synergetic effect was observed, favouring plant development and fruit yield, simultaneously with the increase of compost rates. Compost affected the oxidative metabolism of pepper plants by increasing their antioxidative enzyme activities catalase and superoxide dismutases and the non-enzymatic antioxidants ascorbate and glutathione. Overall, when nitrogen limitation occurred and only compost was used as fertiliser, an oxidative stress took place, whereas in plants grown with nitrate-supplemented compost it did not. Furthermore, these pepper plants experienced a yield increase and, more importantly, an enhancement of the ascorbate content.

Keywords: antioxidants; ascorbic acid; organic fertiliser; reactive oxygen species; nitrogen availability; greenhouse experiment

1. Introduction

Mineral or inorganic fertilisers are widely used in agriculture. Inorganic fertilisers are applied to soils under their easily assimilable forms, providing the principal nutrients to crops [1]. During the last 50 years, inorganic fertilisers have increased agricultural yield and productivity globally. In fact, the global fertiliser nutrient ($N + P_2O_5 + K_2O$) consumption is still increasing [2]. However, inorganic fertiliser doses are commonly overestimated and can produce environmental pollution. For instance, several authors and reports have shown that an excess in the application of nitrogen-based fertilisers can generate contamination in soils, surface and groundwater, and also in the air by releasing greenhouse gases which contribute to global warming [3–6].

Nowadays, soil protection is considered as one of the main concerns in agricultural policies since unpolluted soils are directly correlated to food production and security [7]. To achieve this purpose, increasing the organic matter content in agricultural soils could be a reliable strategy, as the organic matter losses are directly related to soil fertility [8]. Agriculture and the agro-food industry yearly generate an important amount of organic wastes that can be used for obtaining soil fertilisers and

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D.3. ORANGE

CG9. D3

1. Descripción

Orange es un software para la minería de datos. Mediante la programación visual permite la exploración de datos interactiva para un análisis cualitativo rápido con visualizaciones limpias. Realiza análisis de datos sencillos con una visualización de datos inteligente. Dispone de complementos.

La interfaz gráfica de usuario permite centrarse en el análisis de datos en lugar de en el código, mientras que los valores predeterminados inteligentes hacen que la creación rápida de prototipos de un flujo de trabajo de análisis de datos sea extremadamente fácil.

Permite obtener distribuciones estadísticas, diagramas de caja y diagramas de dispersión, o árboles de decisión, agrupaciones jerárquicas, mapas de calor, MDS y proyecciones lineales. Los datos multidimensionales pueden volverse útiles en 2D, especialmente con selecciones y clasificaciones de atributos inteligentes.

Complementos disponibles para extraer datos de fuentes de datos externas, realizar procesamiento de lenguaje natural y extracción de texto, realizar análisis de red, inferir conjuntos de elementos frecuentes y realizar extracción de reglas de asociación.

Single Cell y Quasar son proyectos relacionados con Orange.

Este software se ha usado recientemente en los trabajos de Bezak eta al., 2018; Di Nunno et al., 2023; Dobesova, 2020; Jobbágy et al., 2023; Krstevska et al., 2022 y Saravi et al., 2019)

2. Características técnicas

Programa	orange		
Versión	3.36.1	Año	2023
Tipología	Minería de datos		
Capacidades del programa	Orange es un programa informático para realizar minería de datos y análisis predictivo desarrollado en la facultad de informática de la Universidad de Ljubljana. Consta de una serie de componentes desarrollados en C++ que implementan algoritmos de minería de datos, así como operaciones de preprocesamiento y representación gráfica de datos. Los componentes de Orange pueden ser manipulados desde programas desarrollados en Python o a través de un entorno gráfico.		
Sistema operativo	Unix (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits y arm M1 y M2)		
Tipo de sistema (arquitectura)	64 bits arm M1 y M2	Tipo de licencia	Código Abierto licenciado bajo GNU/GPL (General Public License)
Desarrollador	Bioinformatics Lab at University of Ljubljana, Slovenia, in collaboration with the open source community		
Web	https://orangedatamining.com/		

3. Ejemplos de trabajos científicos

water

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Article

Application of Copula Functions for Rainfall Interception Modelling

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Abstract: Rainfall interception is an important process of the water cycle that can have significant influence on surface runoff and groundwater storage. Since rainfall interception measurements are rare and time consuming, rainfall interception estimation can be made indirectly using different meteorological variables. Experimental data of rainfall interception for birch and pine trees was measured at an experimental plot located in an urban area of Ljubljana, Slovenia in this study. A copula model was applied to predict the rainfall interception using meteorological variables, namely air temperature and vapour pressure deficit data. The copula model performance was compared to some other models such as decision trees, multiple linear regressions, and exponential functions. Using random sampling, we found that the copula model where Khoudraji-Liebscher copula functions were used yielded slightly smaller root mean square error (RMSE) and mean absolute error (MAE) values than other tested methods (i.e., RMSE and MAE results for birch trees were 24.2% and 18.2%, respectively and RMSE and MAE results for pine trees were 25.0% and 19.6%, respectively). The results demonstrate that the copula-based proposed method and other tested models could be used for the prediction of rainfall interception at the considered plot and in the wider surroundings. Furthermore, these models could also be applied for the prediction of rainfall interception for these two tree species in other locations under similar vegetation and meteorological conditions.

Keywords: copula functions; rainfall interception; modelling; pine tree; birch tree; vapour pressure deficit; air temperature; decision trees

1. Introduction

Rainfall interception by vegetation is recognized as an important process of the hydrological cycle by researchers worldwide, influencing surface runoff in a great manner, irrespective of whether they are conducted in natural or urban forests (e.g., [1–6]). Rainfall partitioning can be divided into three main components, namely throughfall, stemflow, and interception loss. Throughfall is a portion of precipitation that either reaches the ground directly without touching the canopy or reaches the ground at a later time by dripping from the saturated canopy. Stemflow is a portion of intercepted precipitation that reaches the ground by flowing down the branches and stem. Interception loss is a portion of rainfall that is intercepted by the vegetation and evaporated back into the atmosphere, never reaching the ground. The process of rainfall partitioning is influenced by different meteorological (e.g., rainfall amount, intensity, raindrop size, raindrop velocity, air temperature, air humidity, wind speed) and vegetation variables (e.g., tree type, canopy characteristics, stem roughness, leaf area index) [4,7–14]. Rainfall amount, duration and intensity are often recognised as the most influential meteorological variables since they decrease rainfall interception [4,14–17]. However, throughfall and stemflow, both of which also decrease rainfall interception, continue after the end of the rainfall event [13,18]. In this

sustainability

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Article

A Combined Clustering and Trends Analysis Approach for Characterizing Reference Evapotranspiration in Veneto

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Abstract: Climate change is having an increasing effect on the water cycle, hindering the proper management of water resources for different purposes. Veneto, Northern Italy, is a region characterized by various climatic conditions, ranging from the coastal area to the inland, which exhibits significant agricultural productivity with high irrigation demand, up to the mountainous area to the north. This study assesses a key aspect of climate change in Veneto by focusing on a crucial hydrological parameter, the reference evapotranspiration (ETo), which is calculated using the Penman–Monteith equation. The K-means algorithm was employed to divide Veneto into nine homogeneous regions, each characterized by specific evapotranspiration and climatic features. Furthermore, the seasonal Mann–Kendall (MK) test and the innovative trends analysis (ITA) method were used to investigate the trends related to monthly precipitation, ETo, and climate variables. The seasonal MK test revealed negative trends in precipitation for all clusters. In contrast, ETo trends appear to be decreasing for some clusters, both on the coast and inland, and increasing for others. The ITA method indicated more pronounced trends for higher values of ETo and precipitation, highlighting significant variations that primarily impact extreme values. Overall, this study's approach, which incorporates clustering and trends analysis methods, provides a detailed depiction of ETo in Veneto, enabling the identification of distinct homogeneous areas and the assessment of evolutionary trends concerning evapotranspiration and precipitation, from the coastal to the mountainous regions.

Keywords: evapotranspiration; clustering; trend analysis; Mann–Kendall test; ITA method

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1. Introduction

Evapotranspiration plays an essential role in water resources planning and management, as it is one of the primary processes in the water cycle. However, directly measuring evapotranspiration is a challenging task. Therefore, estimation methods rely on the analysis of meteorological variables that are easier to measure over time [1]. The United Nations Food and Agriculture Organization (FAO) recommends the use of the Penman–Monteith (PM) equation, which incorporates both radiometric and aerodynamic variables to evaluate ETo [2].

It is important to note that climate change is impacting the hydrological cycle, leading to consequences that primarily affect precipitation and temperature patterns. These changes subsequently have a direct impact on water resources and their utilization for various purposes. The extent of these impacts can vary across different regions, depending on their specific climates and geomorphology, such as altitude and proximity to the sea. Therefore, conducting a spatio-temporal analysis of evapotranspiration trends becomes critical in identifying potential imbalances in water resource management at the regional level.

A spatial characterization of ETo should begin with the identification of homogeneous regions by means of clustering algorithms. Xing et al. [3] applied the rotated empirical orthogonal function (REOF) clustering method to identify eight homogenous ETo regions

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Experiment in Finding Look-Alike European Cities Using Urban Atlas Data

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Abstract: The integration of geography and machine learning can produce novel approaches in addressing a variety of problems occurring in natural and human environments. This article presents an experiment that identifies cities that are similar according to their land use data. The article presents interesting preliminary experiments with screenshots of maps from the Czech map portal. After successfully working with the map samples, the study focuses on identifying cities with similar land use structures. The Copernicus European Urban Atlas 2012 was used as a source dataset (data valid years 2015–2018). The Urban Atlas freely offers land use datasets of nearly 800 functional urban areas in Europe. To search for similar cities, a set of maps detailing land use in European cities was prepared in ArcGIS. A vector of image descriptors for each map was subsequently produced using a pre-trained neural network, known as Painters, in Orange software. As a typical data mining task, the nearest neighbor function analyzes these descriptors according to land use patterns to find look-alike cities. Example city pairs based on land use are also presented in this article. The research question is whether the existing pre-trained neural network outside cartography is applicable for categorization of some thematic maps with data mining tasks such as clustering, similarity, and finding the nearest neighbor. The article's contribution is a presentation of one possible method to find cities similar to each other according to their land use patterns, structures, and shapes. Some of the findings were surprising, and without machine learning, could not have been evident through human visual investigation alone.

Keywords: Urban Atlas; Orange software; land use; machine learning

1. Introduction

The field of artificial intelligence (AI) has made rapid progress in recent years. AI has received tremendous attention from academia, industry, and also the general population. Machine learning (ML) is a subfield of artificial intelligence [1].

Machine learning encompasses learning without any type of supervision (unsupervised learning) and learning with full supervision (supervised learning). Unsupervised learning examines uncategorized data to discover patterns. No correct answers are given to the machine during learning. The natural patterns in data are expected to guide the machine in learning to detect key patterns and group data according to those patterns (i.e., unsupervised learning involves machines attempting to learn "on their own", without assistance from categorized data). Unsupervised learning tasks can be solved as either clustering or association problems, depending on the application [2]. Deep learning (DL) is a special type of machine learning that leverages multiple layers of nonlinear processing units or neurons. The rapid progress in ML can be attributed to three main reasons: vast quantities of available data, powerful computing capabilities, and improvements in algorithms, such as deep neural networks. The unsupervised deep learning method was selected for this study to find similar maps.

water

MDPI

Article

Evaluation of Soil Infiltration Variability in Compacted and Uncompacted Soil Using Two Devices

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Abstract: Infiltration is defined by the expression of the hydraulic conductivity of the soil, which we decided to monitor on an experimental field applying a modern system of land management (control traffic farming). The present study compared two different methods of monitoring the hydraulic conductivity of soil on a selected 16 ha plot of land in the suburbs of the village Kolíňany (Slovak Republic). During the growing seasons, crops such as oilseed rape, winter wheat, spring barley, winter barley, spring peas, and maize alternated in individual years. In addition to the study of hydraulic conductivity, a long-term experiment is underway to investigate the influence of technogenic factors on soil degradation using a system of controlled movement of machines in the field. A mini disk infiltrometer (method one) was used to evaluate the unsaturated hydraulic conductivity of the soil, and a double ring infiltrometer (method two) was used to measure the saturated hydraulic conductivity. Monitoring changes in soil infiltration capacity within the compacted and uncompacted lines required 26 monitoring points (20 for method one and 6 for method two). The first longitudinal line was compacted by an agricultural machinery chassis, and the second line remained uncompressed. The research also created transverse compacted lines at eight monitoring points (six for method one and two for method two). The results did not show a statistically significant difference when examining the effect of soil infiltration monitoring (compacted $p = 0.123$; uncompacted $p = 0.99$). When evaluating the statistical dependence on the compression caused by machinery in the track line, the hypothesis of significance was not confirmed ($p = 0.12$, at the level of 0.05). However, the results showed variability in the value of the difference factor between the two methods, ranging from 0 to 0.24. On average, it can be concluded that the results achieved using the double ring infiltrometer were 4.16 times higher than those measured with the mini disk infiltrometer. The variability of hydraulic conductivity was demonstrated not only in the compacted but also in the non-compacted part of the plot. In some places, the phenomenon of water repellency appeared, which could be caused by the drier location of the targeted plot.

Keywords: control traffic farming; water; sustainability; climate change; hydraulic conductivity

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1. Introduction

The process of water entering the soil is called infiltration, most often through its surface. From a hydrological point of view, the most interesting is infiltration from precipitation. The formation of surface runoff and the associated soil erosion depends on the intensity of the infiltration. Experts' goal is to create such conditions that as much rainfall as possible needed for plants soaks into the soil [1]. As already mentioned, infiltration is the process of water infiltration into the ground. In addition to the classic cases of water infiltration from precipitation, irrigation or melting snow, water can infiltrate the soil from various standing waters such as puddles, lakes, and reservoirs. Other possibilities are through banks, the bottom of streams, or infiltration facilities below the soil surface [2].

pharmaceutics

MDPI

Review

In-Depth Analysis of Physiologically Based Pharmacokinetic (PBPK) Modeling Utilization in Different Application Fields Using Text Mining Tools

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Abstract: In the past decade, only a small number of papers have elaborated on the application of physiologically based pharmacokinetic (PBPK) modeling across different areas. In this review, an in-depth analysis of the distribution of PBPK modeling in relation to its application in various research topics and model validation was conducted by text mining tools. Orange 3.32.0, an open-source data mining program was used for text mining. PubMed was used for data retrieval, and the collected articles were analyzed by several widgets. A total of 2699 articles related to PBPK modeling met the predefined criteria. The number of publications per year has been rising steadily. Regarding the application areas, the results revealed that 26% of the publications described the use of PBPK modeling in early drug development, risk assessment and toxicity assessment, followed by absorption/formulation modeling (25%), prediction of drug-disease interactions (20%), drug-drug interactions (DDIs) (17%) and pediatric drug development (12%). Furthermore, the analysis showed that only 12% of the publications mentioned model validation, of which 51% referred to literature-based validation and 26% to experimentally validated models. The obtained results present a valuable review of the state-of-the-art regarding PBPK modeling applications in drug discovery and development and related fields.

Keywords: physiologically based pharmacokinetic modeling (PBPK); physiologically based biopharmaceutics modeling (PBBM); text mining; topic modeling; modeling and simulations (M&S)

Citation: Krstevska, A.; Đuriš, J.; Ibrić, S.; Cvijić, S. In-Depth Analysis of Physiologically Based Pharmacokinetic (PBPK) Modeling Utilization in Different Application Fields Using Text Mining Tools. *Pharmaceutics* **2023**, *15*, 107. https://doi.org/10.3390/pharmaceutics15010107

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1. Introduction

Modeling and simulation (M&S) is a proven scientific approach that has a profound impact on drug discovery and development processes. Physiologically based pharmacokinetic (PBPK) models represent mechanistic models, which integrate a series of different mathematical equations describing the processes a drug undergoes in a human (or animal) organism. Since PBPK models are based on known anatomical and physiological data, they are very useful for the prediction of pharmacokinetic (PK) and pharmacokinetic-dynamic (PK/PD) behavior of drugs and/or chemicals. The term PBPK modeling dates back to 1937 when Teorell introduced mathematical equations to describe drug concentrations over time in blood and body tissues [1]. However, the interest in PBPK modeling increased during the early 1970s due to the increased availability of computers and numerical integration algorithms [2,3]. The expansion of interest in PBPK modeling has been perceived through the growth in the number of scientific publications that include PBPK modeling in the past decade [3,4]. PBPK modeling finds application in every phase of the drug development process, starting from the early drug discovery phase where limited data are available, continuing all the way to the late stages of drug development. The major advantage of PBPK modeling over other modeling tools used in early drug discovery stages is that PBPK models provide a holistic view of the interplay between different parameters on drugs' PK

water

MDPI

Article

Use of Artificial Intelligence to Improve Resilience and Preparedness Against Adverse Flood Events

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Abstract: The main focus of this paper is the novel use of Artificial Intelligence (AI) in natural disaster, more specifically flooding, to improve flood resilience and preparedness. Different types of flood have varying consequences and are followed by a specific pattern. For example, a flash flood can be a result of snow or ice melt and can occur in specific geographic places and certain season. The motivation behind this research has been raised from the Building Resilience into Risk Management (BRIM) project, looking at resilience in water systems. This research uses the application of the state-of-the-art techniques i.e., AI, more specifically Machin Learning (ML) approaches on big data, collected from previous flood events to learn from the past to extract patterns and information and understand flood behaviours in order to improve resilience, prevent damage, and save lives. In this paper, various ML models have been developed and evaluated for classifying floods, i.e., flash flood, lakeshore flood, etc. using current information i.e., weather forecast in different locations. The analytical results show that the Random Forest technique provides the highest accuracy of classification, followed by J48 decision tree and Lazy methods. The classification results can lead to better decision-making on what measures can be taken for prevention and preparedness and thus improve flood resilience.

Keywords: Artificial Intelligence; machine learning; flood; preparedness; resilience; flood resilience

1. Introduction

Climate change is expected to increase the frequency and intensity of extreme events, including flooding. Across the world, flooding has an enormous economic impact and cost millions of lives. The number of large scale natural disasters have significantly increased in the past few years; this results in considerable impact to human lives, environment and buildings, and substantial damage to societies. During these disasters, vast quantities of data are collected on the characteristics of the event via governmental bodies, society (e.g., citizen science), emergency responders, loss adjusters and social media, amongst others. However, there is a lack of research on how this data can be used to inform how different stakeholders are/can be directly or indirectly affected by large scale natural disasters pre-, during and post-event disaster management decisions. There is a growing popularity and need for the use of Artificial Intelligence (AI) techniques [1] that bring large-scale natural disaster data into real practice and provide suitable tools for natural disaster forecasting, impact assessment, and societal resilience. This in turn will inform on resource allocation, which can lead to better preparedness and

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D.4. WEKA

CG9. D4

1. Descripción

Weka (Waikato Environment for Knowledge Analysis) es una plataforma de software realizada en Java para el aprendizaje automático y la minería de datos. Contine herramientas para la preparación, la clasificación la agrupación en clústeres, la minería de reglas de asociación y la visualización de datos.

Esta plataforma ha sido desarrollada por el Department of Computer Science de la University of Waikato en Hamilton, Nueva Zelanda.

WEKA proporciona implementaciones de algoritmos de aprendizaje que puede aplicar fácilmente a su conjunto de datos. También incluye una variedad de herramientas para transformar conjuntos de datos, como algoritmos de discretización y muestreo. Puede preprocesar un conjunto de datos, introducirlo en un esquema de aprendizaje y analizar el clasificador resultante y su rendimiento, todo sin escribir ningún código de programa (Frank et al., 2016).

Una forma de utilizar WEKA es aplicar un método de aprendizaje a un conjunto de datos y analizar su resultado para aprender más sobre los datos. Otra es utilizar modelos aprendidos para generar predicciones sobre nuevas instancias. Una tercera es aplicar a varios aprendizajes diferentes y comparar su desempeño para elegir uno para la predicción (Frank et al., 2016).

En la interfaz interactiva de WEKA, seleccionas en un menú el método de aprendizaje que deseas. Muchos métodos tienen parámetros ajustables, a los que se accede a través de una hoja de propiedades o un editor de objetos. Se utiliza un módulo de evaluación común para medir el desempeño de todos los clasificadores (Frank et al., 2016).

Esta plataforma se ha usado recientemente en los trabajos de Albdel-Sattar et al., 2023; Al-Dosary et al. 2023; Aleksić et al., 2023 Gonçcalves et al., 2022; Librantz y dos Santos, 2023; Momm et al., 2020 y Tran et al., 2020.

2. Características técnicas

Programa	Weka		
Versión	3.8.6	Año	2021
Tipología	Minería de datos		
Capacidades del programa	Weka (Waikato Environment for Knowledge Analysis) es una plataforma de software para el aprendizaje automático y la minería de datos escrito en Java y desarrollado en la Universidad de Waikato. Contiene una colección de herramientas de visualización y algoritmos para análisis de datos y modelado predictivo, unidos a una interfaz gráfica de usuario para acceder fácilmente a sus funcionalidades.		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits y arm M1 y M2)		
Tipo de sistema (arquitectura)	64 bits arm M1 y M2	Tipo de licencia	Código Abierto licenciado bajo GNU/GPL (General Public License)
Desarrollador	Department of Computer Science of the University of Waikato in Hamilton, New Zealand.		
Web	https://www.cs.waikato.ac.nz/ml/weka/index.html		

3. Ejemplos de trabajos científicos

water

MDPI

Article

Experimental and Modeling Evaluation of Impacts of Different Tillage Practices on Fitting Parameters of Kostiakov's Cumulative Infiltration Empirical Equation

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Abstract: The evaluation and modeling of the water infiltration rate into the soil are important to all aspects of water resources management and the design of irrigation systems for agricultural purposes. However, research focused on experimental studies of infiltration rates in clay soils under different tillage practices remains minimal. Therefore, an empirical prediction model for cumulative water infiltration needs to be created to estimate water depth under different tillage practices. Thus, the present research investigated the impacts of different tillage practices, including plow type (three tillage systems: moldboard, disk, and rotary plows), tillage depth (100 and 200 mm) and four soil compactions levels (0, 1, 3, and 5 tractor wheel passes), on cumulative infiltration behavior in a clay soil under a randomized complete design with three replications. Double-ring infiltration experiments were conducted to collect infiltration data. The research was conducted in three different stages. The first stage was performed through a field test to obtain infiltration data, the second stage involved using a Kostiakov empirical equation ($Z = q \times t^b$) for cumulative infiltration to acquire the fitting parameters of "q" and "b", and in the last stage, we predicted the fitting parameters of "q" and "b" based on soil mean weight diameter, tillage depth, and four soil compaction levels by applying regression data mining approaches in Weka 3.8 software. The results show that the effects of relevant factors on the cumulative water infiltration depth of the soil could be statistically significant ($p < 0.05$). The Kostiakov model, with an average coefficient of determination of 0.939, had a good fitting effect on the cumulative water infiltration depth process of the investigated soil. The average, lowest, and maximum values of the "q" parameter were 2.7073, 2.2724, and 3.1277 mm/min^b, respectively, while for the "b" parameter, they were 0.5523, 0.5424, and 0.5647, respectively. Furthermore, the evaluation of several regression data mining approaches determined that the KStar (K*) data mining approach, with a root mean square error of 0.0228 mm/min^b, a mean absolute error of 0.0179 mm/min^b, and a correlation coefficient of 0.997, was the most accurate method for fitting parameter "q" using the testing dataset. The most accurate method for fitting the parameter "b" estimation was determined to be the Multilayer Perceptron method, with a root mean square error of 0.0026, a mean absolute error of 0.0013, and a correlation coefficient of 0.962, using the testing dataset. Therefore, this research, which consisted of in situ field observation experiments and infiltration modeling of the infiltration process in a clay soil, provides an essential theoretical basis for improving models of the rate of cumulative infiltration. Moreover, the proposed methodology could be employed for simulation of the fitting parameters "q" and "b" for soil water cumulative infiltration processes, not only for irrigation management purposes under regular crop production conditions, but also for the selection of the most suitable tillage practices to modify the soil during the agriculture season to conserve water and prevent yield declines. The results support the understanding of the infiltration processes in a clay soil and demonstrate that tillage practices could reduce the water infiltration rate into the soil.

Keywords: irrigation; machine learning; prediction; empirical infiltration models

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Citation: Abdel-Sattar, M.; Al-Obeed, R.S.; Al-Hamed, S.A.; Aboukarima, A.M. Experimental and Modeling Evaluation of Impacts of Different Tillage Practices on Fitting Parameters of Kostiakov's Cumulative Infiltration Empirical Equation. *Water* **2023**, *15*, 2673. https://doi.org/10.3390/w15142673

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water

MDPI

Article

Employing Data Mining Algorithms and Mathematical Empirical Models for Predicting Wind Drift and Evaporation Losses of a Sprinkler Irrigation Method

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Abstract: The advantage of a sprinkler irrigation method is that it saves up to 50% of water consumption during the application of water, as compared to any other surface irrigation system. To assess the behavior of a sprinkler irrigation method, wind drift and evaporation losses (WDEL) are often employed as important parameters. The predictive capacities of four previous mathematical empirical models and two data mining algorithms, namely, reduced-error pruning tree (REPTree) and artificial neural network (ANN) models, were employed to evaluate the impact of the operating parameters of a sprinkler irrigation method on WDEL. The inputs to the REPTree and ANN models were the working pressure, vapor pressure deficit, air temperature, wind speed, nozzle diameter, and air relative humidity. In the experimental field, for data collection, a solid set of sprinklers and collectors positioned per ASAE standards was employed. Promising results showed remarkable performance for one of the mathematical empirical models tested, with a confidence index value of 0.829. Meanwhile, the REPTree and ANN models presented smaller errors for testing data set and are qualified for use given their confidence index values of 0.956 and 0.964, respectively. The REPTree and ANN algorithms were classified as optimal models, indicating that the use of mathematical experimental models alone is inadequate in operational situations involving the nozzle diameter, working pressure, and other variables.

Keywords: sprinkler irrigation; wind drift; evaporation losses; reduced-error pruning; multilayer perceptron; Weka software

Citation: Al-Dosary, N.M.N.; Maray, S.A.; Al-Hamed, S.A.; Aboukarima, A.M. Employing Data Mining Algorithms and Mathematical Empirical Models for Predicting Wind Drift and Evaporation Losses of a Sprinkler Irrigation Method. *Water* **2023**, *15*, 922. https://doi.org/10.3390/w15050922

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1. Introduction

Irrigation water scarcity is a significant issue that has an impact on agricultural production in arid and semi-arid countries [1]. However, fresh water is mostly used for irrigation [2,3]; additionally, irrigated agriculture today accounts for 70–80% of water consumption worldwide [4–7]. In order to reduce the wastage of precious water resources, research on water conservation should be continued using contemporary irrigation technologies, such as sprinkler and trickle irrigation [8], or using correctly designed and maintained irrigation systems [9,10]. Additionally, the development of water conservation techniques requires a thorough understanding of the variables influencing the operation of a sprinkler irrigation system [11].

When compared to surface irrigation methods, sprinkler irrigation methods can cut irrigation water consumption by up to 50%, while also offering the benefits of excellent quality, affordability, and simplicity of installation [12]. A sprinkler irrigation method is not always preferable to drip irrigation or other types of surface irrigation methods. Because the water is transported through pipes, modern pressurized irrigation techniques, such as sprinkler and trickle watering, help reduce water waste [13]. Additionally, the sprinkler irrigation method is a recommended technique in arid and semi-arid environments, owing

mathematics

MDPI

Article

Using Machine Learning in Predicting the Impact of Meteorological Parameters on Traffic Incidents

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Abstract: The opportunity for large amounts of open-for-public and available data is one of the main drivers of the development of an information society at the beginning of the 21st century. In this sense, acquiring knowledge from these data using different methods of machine learning is a prerequisite for solving complex problems in many spheres of human activity, starting from medicine to education and the economy, including traffic as today's important economic branch. Having this in mind, this paper deals with the prediction of the risk of traffic incidents using both historical and real-time data for different atmospheric factors. The main goal is to construct an ensemble model based on the use of several machine learning algorithms which has better characteristics of prediction than any of those installed when individually applied. In global, a case-proposed model could be a multi-agent system, but in a considered case study, a two-agent system is used so that one agent solves the prediction task by learning from the historical data, and the other agent uses the real time data. The authors evaluated the obtained model based on a case study and data for the city of Niš from the Republic of Serbia and also described its implementation as a practical web citizen application.

Keywords: machine learning; regression; classification; prediction; meteorological parameters; traffic incidents; multi-agent architecture

MSC: 68T05; 68T42

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1. Introduction

The parameters affecting the occurrence of traffic incidents (TI) comprise three main groups, and they are as follows: human factors, vehicle and environment [1]. However, in [2], the authors divide the main factors into five groups, i.e., in addition to the listed three groups, they add roadway as well as occupants and other road users, and in [3], the authors consider more types of parameters without any groups; therefore, it could be concluded that there is no single taxonomy. In this paper, the authors consider the influence of the mentioned third group, environmental factors, and in it, just the meteorological subgroup which belongs to a wider subgroup of atmospheric parameters from the environment factors group (Dastoorpoor et al. [4]). The prediction of the impact of atmospheric parameters on TI is an important task for solving one global, serious problem because they cause not only human losses but also economic damages. By 2030, TIs are predicted to become the sixth leading cause of death, overtaking cancer [5], i.e., the seventh leading cause of death, and overtaking HIV/AIDS [6] worldwide. TIs also have an economic importance because they cause 3% of the gross domestic product yearly loss globally and roughly double that in lower-middle-income countries [6].

Having in mind the above-mentioned data on the significantly expressed negative consequences of the occurrence of TI on human lives and the economy, it is obvious that the previously mentioned prediction of the influence of various (including meteorological), factors is one important task in preventing their occurrences. This process of predicting

remote sensing

MDPI

Article

Mapping Areas Invaded by *Pinus* sp. from Geographic Object-Based Image Analysis (GEOBIA) Applied on RPAS (Drone) Color Images

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Abstract: Invasive alien species reduce biodiversity. In southern Brazil, the genus *Pinus* is considered invasive, and its dispersal by humans has resulted in this species reaching ecosystems that are more sensitive and less suitable for cultivation, as is the case for the restingas on Santa Catarina Island. Invasion control requires persistent efforts to identify and treat each new invasion case as a priority. In this study, areas invaded by *Pinus* sp. in restingas were mapped using images taken by a remotely piloted aircraft system (RPAS, or drone) to identify the invasion areas in great detail, enabling management to be planned for the most recently invaded areas, where management is simpler, more effective, and less costly. Geographic object-based image analysis (GEOBIA) was applied on images taken from a conventional RGB camera embedded in an RPAS, which resulted in a global accuracy of 89.56%, a mean kappa index of 0.86, and an F-score of 0.90 for *Pinus* sp. Processing was conducted with open-source software to reduce operational costs.

Keywords: *Pinus*; RPAS; drone; GEOBIA; machine learning

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1. Introduction

Invasion by exotic species represents one of the greatest threats to biodiversity conservation at a global scale [1] and is indicated by experts as capable of compromising the supply of ecosystem services even in protected areas [2]. As a result, it is important to develop methods for controlling exotic species, especially in natural areas with difficult access.

Experts emphasize that invasion cases are frequent in protected areas, despite their recognized importance in in situ biodiversity conservation. Invasions occur even in conservation units (CUs). They are protected areas under special management regimes in Brazil, created to preserve ecosystems and provide them with a management structure and resources for immediate corrective action.

These invasions in protected areas represent a serious concern throughout the country and the world [3]. In general, protected areas such as CUs in Brazil are extensive territories and usually have reduced staff for management and inspection activities. The total area protected by 334 federal CUs is 1,714,241.92 km2, while the total number of Chico Mendes Institute for Biodiversity Conservation (ICMBio) employees is 3603 [4,5].

Even with all this protecting infrastructure, it should be noted that the dispersion of invasive species is closely associated with human presence, as demonstrated in a global evaluation conducted by Van Kleunen et al. [6], who, through the GloNAF project [7], found that human pressure has modified the geographic composition and global distribution

sustainability

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Article

Intelligent Clustering Techniques for the Reduction of Chemicals in Water Treatment Plants

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Abstract: Currently, the use of intelligent models for decision making in the water treatment process is very important, as many plants support their implementation with the aim of obtaining economic, social, and environmental gains. Nevertheless, for these systems to be properly modeled, the data should be carefully selected so that only those that represent good operating practices are used. Thus, this study proposes an approach for identifying water quality and operational scenarios using the expectation maximisation (EM) and self-organising maps (SOMs) techniques when using data from a water treatment plant. The results showed that both techniques were able to identify quantities of different scenarios, some similar and others different, allowing for the evaluation of differences in a robust way. The EM technique resulted in fewer scenarios when compared with the SOMs technique, including in the cluster selection process. The results also indicated that an intelligent model can be trained with data from the proposed clustering, which improves its prediction capacity under different operating conditions; this can lead to savings in chemical product usage and less waste generation throughout the water treatment process, which is in good agreement with cleaner production practices.

Keywords: clustering; expectation maximisation; self-organising maps; water quality scenarios; coagulant dosage; cleaner production practices

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1. Introduction

Water treatment and supply plants are becoming important for ensuring the availability and quality of this essential resource for human health, which is mainly due to the increasing demand for water in urban areas [1].

In this context, water treatment plants (WTPs) are mainly designed for the removal of substances and microorganisms present in the water that is available in watersheds, and the plants make the water suitable for consumption [2,3]. Throughout the water treatment process, several chemicals are used to adjust the pH to ensure disinfection and enable water coagulation [4–6]. The number of chemicals necessary depends on the quality of the raw water collected, which may vary by season or by river or dam degradation [7,8]. The reduction of these non-renewable natural resources in the processing could help to mitigate environmental impacts [9].

Coagulation is the most important step in the existing WTP processes, which consists of destabilizing dirt particles so that they are retained in subsequent procedural steps [10,11]. The coagulation step consists of a complex, non-linear process and has several physical and chemical parameters that impact the determination of dosage reference values [12,13].

The jar test assays consist of a traditional laboratory method for determining the appropriate coagulant dosages depending on the different existing raw water qualities [14,15]. This test is long-lasting and requires significant labor from the people involved [16]. Another way to determine appropriate dosage is to use the operator's experience in adjusting the reference values in cases where there are changes in the characteristics of the collected raw water [17,18].

remote sensing

MDPI

Article

Crop-Type Classification for Long-Term Modeling: An Integrated Remote Sensing and Machine Learning Approach

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Abstract: Long-term temporal and spatial information of crop type supports a wide range of applications including hydrological and climatological studies. In the U.S., yearly crop data layers (CDLs) are available starting in the early 2000s and have been developed using combined field information and sets of temporal imagery from multiple sensors. Development of long-term crop-type layers similar to CDLs is restricted by reduced accessibility to imagery and the necessary auxiliary datasets. In this study, a procedure to generate a historical crop type was developed and evaluated. Time series of Normalized Difference Vegetation Index (NDVI) datasets from Landsat 5 TM sensor for the Lower Bear Creek watershed were collected and processed. Object-based pseudo phenology curves, represented by the NDVI time series, were generated using noise filtering and dimensionality standardization procedures for the years 1985, 1990, 1995, 2000, and 2005. Classifiers were developed and evaluated using random-forest machine learning algorithms and CDL datasets as the reference. Increased generalization performance was obtained when the model was developed using multi-year datasets. This can be attributed to improved crop type representation during the training phase coupled with characterization of yearly variations due to natural (weather) and anthropogenic factors (farming management). Source of uncertainties were the presence of multiple crops within objects, phenological similarities between soybean and corn/maize, and the accuracy of CDL itself. The proposed procedure supports the development of historic crop types for long-term studies at the field scale in agricultural watersheds.

Keywords: crop-type classification; random forest; cropland data layer; agricultural watershed

1. Introduction

Datasets on crop type classification and its distribution in space and time support a wide range of direct applications and can be incorporated into a variety of environmental and hydrologic models. The latter allow us to assess the impact of agriculture on the environment, and conversely, the impact of the environment on agriculture [1,2]. These datasets support government agencies, private sector organizations, scientists, educators, and others seeking an improved understanding of cropland spatiotemporal variations and make informed decisions on farming and conservation practices [2,3]. Applications include, but are not limited to, crop yield estimation and prediction [1], natural hazard (e.g., floods and droughts) impact assessment on agricultural commodities [4–6], and nonpoint source pollution quantification and mitigation [5,6]. For the latter, hydrological watershed models, in particular the annualized agricultural non-point source (AnnAGNPS) [7,8] and the Soil and Water Assessment Tool (SWAT) [9,10], rely heavily on spatiotemporal crop type information to characterize agricultural watershed and best represent existing conditions of land use and farming practices.

applied sciences

MDPI

Article

Novel Ensemble Landslide Predictive Models Based on the Hyperpipes Algorithm: A Case Study in the Nam Dam Commune, Vietnam

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Abstract: Development of landslide predictive models with strong prediction power has become a major focus of many researchers. This study describes the first application of the Hyperpipes (HP) algorithm for the development of the five novel ensemble models that combine the HP algorithm and the AdaBoost (AB), Bagging (B), Dagging, Decorate, and Real AdaBoost (RAB) ensemble techniques for mapping the spatial variability of landslide susceptibility in the Nam Dan commune, Ha Giang province, Vietnam. Information on 76 historical landslides and ten geo-environmental factors (slope degree, slope aspect, elevation, topographic wetness index, curvature, weathering crust, geology, river density, fault density, and distance from roads) were used for the construction of the training and validation datasets that are the prerequisites for building and testing the proposed models. Using different performance metrics (i.e., the area under the receiver operating characteristic curve (AUC), negative predictive value, positive predictive value, accuracy, sensitivity, specificity, root mean square error, and Kappa), we verified the proficiency of all five ensemble learning techniques in increasing the fitness and predictive powers of the base HP model. Based on the AUC values derived from the models, the ensemble ABHP model that yielded an AUC value of 0.922 was identified as the most efficient model for mapping the landslide susceptibility in the Nam Dan commune, followed by RABHP (AUC = 0.919), BHP (AUC = 0.909), Dagging-HP (AUC = 0.897), Decorate-HP (AUC = 0.865), and the single HP model (AUC = 0.856), respectively. The novel ensemble models proposed for

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D.5. FRAGSTATS

CG9. D5

1. Descripción

Fragstats es un programa informático diseñado para calcular y analizar una amplia variedad de patrones espaciales para cuantificar la estructura (es decir, composición y configuración) de los paisajes. El paisaje objeto de estudio está definido por el usuario y puede representar cualquier fenómeno espacial. El software original fue expuesto por primera vez en 1995 en asociación con la publicación de un informe técnico del Servicio Forestal del Departamento de Agricultura de Estados Unidos (USDA). Desde entonces el software ha sido renovado en varias ocasiones (versiones 3 y 4) con varias mejoras como por ejemplo la 3.4. que permitía acomodar ArcGIS 10 o la versión actual (4.2.) que posee una nueva interfaz con una amplia variedad de métodos de muestreo para el análisis de sub-paisajes.

La versión original de Fragstats fue desarrollado por el Dr. Kevin McGarigal y Barbara Marks de la Oregon State University. En las siguientes versiones han participado otros programadores como Eduard Ene, Chris Holmes o el Dr. San Cushman.

Fragstats se ha usado en múltiples investigaciones y trabajos científicos. Este software se ha usado recientemente en los trabajos de Giuliani et al., 2022; González et al., 2019; Ku, 2020; Paonam y Chatterjee, 2023; Ramirez et al., 2019; Sanguet et al., 2023 y Withaningsih et al., 2022.

2. Características técnicas

Programa	FragStats		
Versión	4.2.681	Año	2023
Tipología	Geoestadística		
Capacidades del programa	Software diseñado para computar una amplia variedad de métricas de paisaje para elaborar mapas específicos. Fragstats diferencia entre composición y configuración del paisaje, así como qué aspecto está siendo cuantificado por cada una de las medidas aportadas. Permite calcular una gran variedad de estadísticas de cada píxel del paisaje, así como para su área total.		
Sistema operativo	Windows (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Freeware
Desarrollador	Eduard Ene & Kevin Mcgarigal		
Web	https://fragstats.org/		

3. Ejemplos de trabajos científicos

land

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Article

Downscaling Switzerland Land Use/Land Cover Data Using Nearest Neighbors and an Expert System

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Abstract: High spatial and thematic resolution of Land Use/Cover (LU/LC) maps are central for accurate watershed analyses, improved species, and habitat distribution modeling as well as ecosystem services assessment, robust assessments of LU/LC changes, and calculation of indices. Downscaled LU/LC maps for Switzerland were obtained for three time periods by blending two inputs: the Swiss topographic base map at a 1:25,000 scale and the national LU/LC statistics obtained from aerial photointerpretation on a 100 m regular lattice of points. The spatial resolution of the resulting LU/LC map was improved by a factor of 16 to reach a resolution of 25 m, while the thematic resolution was increased from 29 (in the base map) to 62 land use categories. The method combines a simple inverse distance spatial weighting of 36 nearest neighbors' information and an expert system of correspondence between input base map categories and possible output LU/LC types. The developed algorithm, written in Python, reads and writes gridded layers of more than 64 million pixels. Given the size of the analyzed area, a High-Performance Computing (HPC) cluster was used to parallelize the data and the analysis and to obtain results more efficiently. The method presented in this study is a generalizable approach that can be used to downscale different types of geographic information.

Keywords: land cover; land use change; downscaling approach; Switzerland; geographic information system; aerial photo interpretation; topographic map; inverse distance weighting; expert system

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1. Introduction

1.1. Pressures on Land Resources in Switzerland

The Swiss Federal Department of Environment, Transport, Energy and Communications (DETEC) in its 2016 Strategy stated that by 2030, Switzerland is aiming at becoming a sustainable country while remaining an attractive and competitive business location with a high quality of life [1]. This ambitious objective is presently challenged by several trends such as population growth, increased mobility, energy demand, high consumption of resources, urbanization, loss of biodiversity and associated ecosystem services, and the digitalization of society along with related big data [2]. These trends have an important impact on the environment. Therefore, protecting the environment is a central mission for the Swiss Government, who wants to promote and adopt more sustainable approaches for the exploitation of natural resources [3]. To this end, actions such as protecting natural resources, improving urban planning, reducing emissions of greenhouse gases, preserving water quality, retaining biodiversity and ecosystem services, protecting soils, and preserving countryside are essential [4–6].

All these trends are also placing unprecedented demands on land. Between 1985 and 2009, 15% of the country's surface area changed [7]. Settlement and urban areas have

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Vegetation patterns in a South American coastal wetland using high-resolution imagery

Eliana Gonzalez, Gabriela González Trilla, Laura San Martin, Rafael Grimson & Patricia Kandus

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sustainability

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Article

Exploring the Spatial and Temporal Relationship between Air Quality and Urban Land-Use Patterns Based on an Integrated Method

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Abstract: The deterioration of air quality in urban areas is often closely related to urbanization, as this has led to a significant increase in energy consumption and the massive emission of air pollutants, thereby exacerbating the current state of air pollution. However, the relationship between urban development and air quality is complex, thus making it difficult to be analyzed using traditional methods. In this paper, a framework integrating spatial analysis and statistical methods (based on 170 regression models) is developed to explore the spatial and temporal relationship between urban land use patterns and air quality, aiming to provide solid information for mitigation planning. The thresholds for the influence of urban patterns are examined using different buffer zones. In addition, the differences in the effects of various types of land use pattern on air quality were also explored. The results show that there were significant differences between 1999 and 2013 with regards to the correlations between land use patterns and air pollutant concentrations. Among all land uses, forest, water and built-up areas were proved to influence concentrations the most. It is suggested that the developed framework should be applied further in the real-world mitigation planning decision-making process

Keywords: urban land-use pattern; spatial-temporal relationship; air quality; integrated method

1. Introduction

The intensification of global urbanization has exacerbated the negative impact of various environmental factors in urban areas, thus threatening the sustainability of future urban development on multiple fronts. In order to ensure the sustainability of urban environments, the use of urban or environmental planning as tools to formulate countermeasures has become an issue of great concern among government agencies. Of the various natural and man-made hazards, air pollution has been increasingly regarded as an important topic of research because it exerts constant tangible and intangible effects on the physical and mental health of urban residents, thereby indirectly affecting the social and economic activities of urban areas. In recent years, countries around the world have gradually begun to examine the causes and negative effects of air pollution in urban areas from the perspectives of sustainable development and urban planning, as well as the possible adaptations and mitigations to address these issues. From this, we can see that air pollution has a considerable impact on the sustainable development of cities [1–3]. In addition, numerous studies have shown that air pollution has a significant impact on human health [4–6]. The most common air pollutants in cities include carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons (HC), suspended particulate matter (SPM, including PM10, PM2.5), heavy metals (HM), ozone (O_3), smog, and chlorofluorocarbons (CFC). For example, residents living near major traffic thoroughfares were subject to long-term exposure to traffic-related air pollutants, such as black smoke and NO_2, which lead to increased cardiopulmonary mortality [7].

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Evaluating the Land Use Land Cover Dynamics of Loktak Lake, A Ramsar Wetland of International Importance in North East India

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ABSTRACT
In fragile transitional freshwater ecosystems, such as wetlands, the increasing anthropogenic and natural pressures, including climate change and industrialisation, have impacted the land use/land cover (LULC). The present study aims to identify the LULC changes occurring in Loktak Lake, a Ramsar Wetland of International Importance, included in the Montreux Record between 2009 and 2020 using LANDSAT imageries. In order to quantify the LULC, a Maximum Likelihood Classifier was carried out in Arc GIS 10.8.1. A total of six land use classes were classified viz., open water body, athaphum, phumdi, built up, agriculture and barren area. It also attempts to undertake landscape modelling to look at the fragmentation of phumdi class through FRAGSTATS utilising the Number of Patches (NP), Patch Density (PD), Largest Patch Index (LPI) and Cohesion metrics. An overall decline in phumdi, athaphum, agriculture and open water body land uses at the rate of 5.9, 14.54, 110.1 and 1%, respectively, was observed. Meanwhile, built-up and barren land uses showed an overall increase at the rate of 18.31 and 31.25%, respecively. These LULC changes observed have been primarily because of anthropogenic factors, which threaten an already fragile ecosystem. The landscape modelling exercise showed that phumdi is aggregated at the innermost portions of the lake. It also showed that the patches of phumdi were higher in years 2011 and 2020, which may be due to the use of phumdi strips in athaphum (fish farms on the lake). The study indirectly revealed the effectiveness of past management actions by relevant organisations, as remotely sensed information requires ground validation. It also highlighted the absence of baseline data information and emphasised integrating present, past and future LULC modelling for management purposes.

Key words: Fragstats, Montreux record, Land use land cover change, Maximum Likelihood Classifier, Loktak Lake management

INTRODUCTION

The inherently complex nature of wetlands makes them one of the richest ecosystems, with a net worth of natural wetlands estimated to be at 47.4 $ trillion/ year, accounting for almost 43.5% of other natural ecosystems (Davidson 2019). However, wetlands are also a deteriorating system shown by the steady decline of an average of 35% globally from 1970 to 2015 (Darrah et al. 2019). The deterioration is marked by factors such as agriculture, urbanization, aquaculture, and industrial development, all of which are significant land use land cover changes (LULC) (Anonymous 2021a, Baluut Dajud et al. 2022). Although the LULC terms are used interchangeably, land cover denotes the physical characteristics that cover the earth's surfaces, while land use is the activities carried out by humankind to fulfil a particular objective by using the resources of the land (Jamal and Ahmed 2020). Further, essential policy processes, including RSP 2016-2024 and Sustainable Development Goals (SDGs), have overarching goals that embrace addressing the drivers of wetland loss and degradation and enhancing implementation (RSP 2016-2024). More specifically, SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 14 (Life below water), and SDG 15 (Life below Land) are directly related to wetlands and are also areas where LULC changes are discernible.

Remote sensing and GIS have been extensively used in global wetland studies, such as LULC changes in wetlands and mapping hydrological processes (Jensen et al. 1995, Rebelo et al. 2009, Nagabhatla et al. 2010). Multiple multispectral datasets viz., LANDSAT Multispectral Scanner (MSS), Thematic Mapper (TM) and the Operational Land Imager (OLI), IKONOS-2 and SPOT 1-5 datasets have also been used widely (Mahdavi et al. 2018). Additionally, changes in the landscape can also be detected using landscape metrics through

resources

MDPI

Article

Landscape Fragmentation, Ecosystem Services, and Local Knowledge in the Baroro River Watershed, Northern Philippines

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Abstract: Landscape fragmentation, the breaking up of land use type into smaller parcels, is damaging watersheds worldwide. Without addressing its causes, landscape fragmentation can permanently destroy habitats and compromise ecosystem services (ES) that a watershed provides. This paper aims to establish associations between watershed landscape fragmentation and ES by integrating science (satellite imageries and fragmentation analyses) and local geographic knowledge (key informant interviews and focus group discussions) at different time periods. Using the case of the Baroro River Watershed in Northern Philippines, this paper posits that local knowledge, when integrated with scientific knowledge, becomes a significant medium through which watershed landscape fragmentation and declining quality of ES can be better understood and addressed. Results also indicate that people's experiences and knowledge on ES coincide with watershed landscape fragmentation as evidenced by satellite images and fragmentation analyses done at different time periods. This implies that people's knowledge is well grounded on facts and complements scientific knowledge necessary in crafting more effective landscape policies that can tackle watershed fragmentation. Study results are also crucial in providing information to serve as inputs in the development of a more robust watershed management plan; particularly in implementing sustainable land uses without sacrificing the watershed's overall integrity.

Keywords: landscape fragmentation; watershed; ecosystem services; local knowledge; Philippines

1. Introduction

Tropical forests are known as the richest terrestrial ecosystems in the world in terms of flora and fauna as well as structural complexity [1,2]. These forests can be found inside watersheds, where both surface and groundwater emanate and drain into a common outlet. Watersheds are landscapes composed of a mix of local ecosystems and land uses covering a wide area. Currently, most watershed landscapes are being threatened by fragmentation, mainly caused by anthropogenic activities. As species are becoming extinct due to habitat destruction, the numerous ecosystem services (ES) being provided by these watersheds are being compromised at an alarming rate, which adversely affects both socio-ecological systems and human well-being. Ecosystems are indispensable sources of various goods and services needed by humans to survive, and keep natural processes intact [3,4].

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Article

Mapping Ecological Infrastructure in a Cross-Border Regional Context

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Abstract: Facing the decline of biodiversity worldwide, the conservation of the remaining natural and semi-natural areas is fundamental. To do so, the concept of green infrastructure has gained attention recently. This case study presents the method developed to identify the green infrastructure in a cross-border, urbanized territory between Switzerland and France in the area of influence of the city of Geneva. The first part of the methodology consists of calculating and mapping the inputs aggregated in four pillars: (i) the distribution of habitats as well as the predicted distribution of hundreds of plant and animal species, (ii) the supply of five ecosystem services, (iii) the functional connectivity for three animal species and the light pollution and (iv) five indices of landscape's structure. These inputs are then used to run a prioritization model to identify the areas with the highest ecological interest according to these weighted inputs. The cross-border situation of this case study had impacts on the way the input data were gathered and weighted and on the way the output was created to consider the expectations of the three main local authorities involved, without creating any legal obligations on the implementation of the green infrastructure. As a positive sign of the usefulness of these results, the resulting maps were immediately transferred to the land use planners in charge of developing ambitious visions of the "Grand Genève" territory for 2050 in alignment with 10 objectives of ecological transition as recently agreed and signed by local authorities. The method presented in this article is flexible and includes a broad description of biodiversity, supporting a reliable network of areas with high ecological values for conservation purposes and human well-being.

Keywords: SDM; conservation; biodiversity; ecosystem services; connectivity; prioritization

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1. Introduction

Global biodiversity is under a major crisis at every level and its genetic, species and ecosystem diversity is declining rapidly [1,2]. The destruction of natural habitats for agriculture and/or urbanization is the main cause of its decline and is directly linked to our way of occupying terrestrial and marine surfaces as well as to our consumption patterns [3–7]. Biological diversity decline might ultimately alter ecosystem functions such as productivity, stability and resilience, jeopardizing our food and water security as well as our socio-economic well-being [8–17]. Thus, the conservation of the remaining natural and semi-natural areas is fundamental, especially in urbanized environments where urbanization represents an additional pressure.

Green infrastructure (GI) is defined as a network of (semi-)natural areas allowing structural and functional connectivity of the landscape where biodiversity and ecosystem

forests

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Article

Analysis of the Structure and Ecological Function of an Extreme Landscape in a Tropical Region of West Java, Indonesia

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Abstract: An extreme landscape is a spatially heterogeneous area with unusual topography that is prone to natural disasters but still exhibits interrelated structures and functions. One of the important functions of an extreme landscape is its ecological function. This study aimed to determine the structure and reveal the ecological functions of an extreme landscape in a tropical region of West Java, with special reference to Rongga Sub-district. The method used was a combination of remote sensing techniques and geographic information systems, which were required to process, analyze, and interpret Landsat 8 OLI/TIRS data. The landscape structure was quantified by landscape metrics, after which an analysis of ecological functions was carried out based on the constituent elements of the landscape. The results showed that the landscape structure of Rongga Sub-district consists of various elements of agroforestry land, open fields, settlements, shrubs, plantations, and rainfed and irrigated rice fields. Additionally, secondary forest land acted as a landscape matrix where rivers crossed as natural corridors. The amount of each element varied; agroforestry land had the highest value, indicating that this element showed a high degree of human intervention. Each patch was adjacent to other patch types, and the landscape diversity was quite high. The extreme topography of Rongga Sub-district supports the landscape connectivity and consequently the presence of wild animals in this area. Therefore, Rongga Sub-district has an essential ecological function as a refuge for protected animals living in non-conservation areas.

Keywords: ecological function; landscape structure; remote sensing; GIS

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1. Introduction

A landscape is a spatially heterogeneous area [1] characterized by a mosaic of patches differing in size, shape, content, and history [2]. In general, landscapes are formed by the interaction between natural (ecological) factors and human factors [3]. As a result of this interaction, landscapes have a variety of visual, cultural, and ecological constructs. These landscape characteristics make an area unique because of the different element patterns in certain landscape types [4].

A landscape shows the same three basic characteristics of all living systems: structure, function, and dynamics. Structure is the spatial relationship between the different ecosystems (or elements) that make up a landscape. Function is the interaction between spatial elements: the flow of energy, materials, and species between ecosystem components and the intrinsic behavior of complex mosaics. Dynamics comprises the evolution and changes in the structure and function of complex mosaics over time [5].

The structure of a landscape has an important influence on its functional characteristics. Any changes in the landscape structure, whether spatial or temporal, affect energy and material flows, the feasibility and habitability of the landscape, ecological stability, and

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Withaningsih, S., Parikesit, P., Malik, A.D. y Rahmi, M.A. (2022). Analysis of the Structure and Ecological Function of an Extreme Landscape in a Tropical Region of West Java, Indonesia. Forests. [Online]. 13 (1). p.p. 115. http://dx.doi.org/10.3390/f13010115

E. CALIDAD CARTOGRÁFICA

E.1. MAPANALYST

CG9. E1

1. Descripción

MapAnalyst es una aplicación de software para el análisis de la precisión de mapas antiguos. Su objetivo principal es calcular las cuadrículas de distorsión del mapa antiguo y otros tipos de visualizaciones que ilustran la precisión geométrica y la distorsión de este tipo de mapas.

MapAnalyst es un software gratuito y de código abierto. Se trata de una aplicación Java que se ejecuta en todas las principales plataformas informáticas. Permite la identificación y gestión eficiente de puntos de control en un mapa antiguo y en un mapa de referencia (más preciso y actual), calculando su grado de precisión mediante datos cuantitativos y gráficos como las mallas de distorsión, los vectores de error e isolíneas de escala y rotación.

Este programa es desarrollado y mantenido por el Dr. Bernhard Jenny (Monash Univeristy, Melbourne). La mayoría de la programación se llevó a cabo en el Instituto de Cartografía y Geoinformación de ETH Zurich hasta su lanzamiento definitivo en 2007.

Las principales investigaciones en las que se ha usado MapAnalyst se basan en el análisis de la precisión planimétrica o geométrica de diferente cartografía antigua. Este software se ha usado recientemente en los trabajos de Bartos-Elekes, 2023; Cevelli y Pindozzi, 2022; Martí y Romanillos, 2023; Pędzich, 2023; Sahin et al., 2023; Statuto et al, 2017 y Van Schaik et a., 2023

2. Características técnicas

Programa	MapAnalyst		
Versión	1.3.35	Año	2019
Tipología	Calidad cartográfica		
Capacidades del programa	MapAnalyst es una aplicación software para el análisis de la precisión espacial de mapas antiguos. Su objetivo principal es el cálculo de cuadrículas de precisión geométrica y la distorsión de los mapas antiguos. MapAnalyst utiliza pares de puntos de control en un mapa antiguo y uno actual de referencia. Los puntos de control se usan para construir cuadrículas de distorsión, vectores de desplazamiento, círculos de precisión e isolíneas. Además, el programa calcula la escala, la rotación y los indicadores estadísticos de precisión del mapa antiguo analizado.		
Sistema operativo	Linux (32 y 64 bits)		
	Windows (32 y 64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	32 y 64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU/GPL (General Public License)
Desarrollador	Bernie Jenny, Monash University, Australia		
Web	https://mapanalyst.org/index.html		

3. Ejemplos de trabajos científicos

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Zsombor Bartos-Elekes*

Digital tools concerning the analysis of maps representing Hungary and Transylvania (1683–1711)

Keywords: Gábor Hevenesi, Giovanni Morando Visconti, Johann Christoph Müller, Nicolaus Visscher, Frederik de Wit.

Summary: As a result of the war between the Holy League and the Ottoman Empire, Hungary and Transylvania became part of the Habsburg Empire. During and shortly after the war important maps of these newly acquired territories were drawn by members of the Habsburg army and of the Society of Jesus.
Among these early works is the manuscript map series of the Hungarian and Transylvanian counties (*Mappae Comitatuum Regnum Hungariae*), kept in the collection of the Jesuit scholar Gábor Hevenesi. The maps delineated the Hungarian counties surprisingly differ from the printed pocket atlas of Hungary supervised by Hevenesi (*Parvus Atlas Hungariae*, 1689), but they are similar to the well-known Dutch maps of Hungary by De Wit and by Visscher. The maps delineated the Transylvanian counties are similar to the manuscript and printed maps versions of Transylvania (*Mappa della Transilvania*, 1699) by Giovanni Morando Visconti and to one of the manuscript map of Johann Christoph Müller (*Mappa Geographica Transylvaniae*). Almost all of these above maps are undated; the authorship of some maps is unclear.
The author of the present paper has analyzed the maps using the following digital tools: rectification of the maps (in Global Mapper), their accuracy analysis (in MapAnalyst) and the compilations of geo-referenced gazetteers (in Microsoft Excel). These methods has been used to distinguish the source maps and the copied ones; to fix the years when these undated maps were drawn; to clarify the roles of the authors; to understand the correlation between these maps.

Historical background

The territory of Hungary in the Middle Ages was torn in three parts: the Kingdom of Hungary had Habsburg kings; the Principality of Transylvania survived by paying taxes to the Turks; the occupied territory by the Ottoman Empire was stuck between them. In 1684, the Holy League started the reconquering war. At the beginning of 1699, the representatives of the Holy League and of the Ottoman Empire made peace at Karlowitz (Sremski Karlovci). The High Porte gave up all its previously conquered territories in Hungary, except for Temesköz (Banat) and Szerémség (Syrmia), by which the Habsburgs grew in size. Subjugation by the Ottomans was succeeded by Habsburg oppression, which led to the Kuruc War of Independence in 1703. Without any outside help, the uprising lost in 1711. After another war, in 1718, the remaining part of medieval Hungary also became part of the Habsburg Empire. (Köpeczi 1990: 359–379)

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applied sciences

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Article

The Historical Transformation of Peri-Urban Land Use Patterns, via Landscape GIS-Based Analysis and Landscape Metrics, in the Vesuvius Area

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Abstract: Peri-urban areas constitute an enormous resource in terms of natural capital, landscape heritage and economic activities, but, at the same time, they are often affected by physical and socio-economic degradation, drawing the attention of decision makers and planners. Many studies have focused on these contexts both in terms of suburbs, with a close dependence on urban centers, and new land typologies. The present paper focuses on documentary evidence of the direct impacts of urban growth on rural lands. The study area entails the Vesuvius National Park, which, belonging the Naples metropolis, is well-known for its historical, geo-morphologic and naturalistic value. Furthermore, the area has a history of high-quality cartographic production: the 1817, 1907, 1960, 2009 time steps maps were digitized, georeferenced, vectorized and compared in a GIS environment. The results highlight a strong change in land-use, in vineyards and urban class types, with a more disaggregated landscape mosaic. The approach shows that the historical modeling of land-use changes supports the understanding of current land-use dynamics and landscape patterns. The study also shows the need to integrate landscape planning and landscape ecology approaches, highlighting the close interactions between urban, agricultural and natural areas, for the purpose of supporting decision makers in land-use management and conservation policies.

Keywords: urban neighbour; historical maps; land use change; landscape metric; Geographic Information System (GIS)

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1. Introduction

Agro-forest land constitutes an enormous resource in terms of natural capital and cultural heritage, in addition to the economic/productive potentialities connected with primary sector activities. However, at the same time, these areas demonstrate a highly transformable character, due to their limited physical inertia, moderate transformation costs and position factors. The urban growth is considered one of the most important driving forces in shaping landscapes, with direct and strong long-term impacts on agro-forest land, with this decreasing with the distance from the urban centres [1]. Thus, within the main type of agro-forest lands, peri-urban areas hold an especially fragile and vulnerable status, as they still have a high potential for transformability, due to the close physical, functional and perceptive relationship with urban areas, which represent the most extreme expression of the anthropogenic transformation of the environment.

The unstable nature of peri-urban areas makes them particularly susceptible to problems and critical issues; among them, physical and social marginality (the suburbs) is undoubtedly a constant issue, with important repercussions in terms of the productivity,

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The naïve map of the sixteenth century roads in Spain

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ABSTRACT

This paper presents a naïve map that attempts to reflect the vision that Philip II and his advisors probably had of the Spanish road network in the second half of the sixteenth century, a crucial aspect for the choice of the seat of the capital of the kingdom. The elaboration of the naïve map was carried out in two phases: in the first, the road network was reconstructed based on a thorough revision of the primary sources that have survived to the present day. As these sources showed evident problems of completeness, the network was completed using mathematical methods, which were statistically contrasted. The analysis carried out is an important novelty since it shows that most of the transport in the Iberian Peninsula was channeled through the center following a radial structure with six principal axes two centuries before what has been traditionally considered.

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KEYWORDS
Road network; Philip II; capital city; Spain; naive map

1. Introduction

The choice of Madrid as the capital of the Spanish Empire by Philip II in 1561 was an event of great historical significance and continues to be the subject of intense debate from both academic and social points of view (Alvar Ezquerra, 1989; Pablo-Martí et al., 2022; Ringrose, 1983). The choice of a nation's capital has, among many other factors, an obvious geographical component. The quality of communications with the rest of the territory or the ease of supply are issues of great relevance that must inevitably be considered.

Although the need for a detailed justification of the choice of the capital would have been far from the mentality of an authoritarian king like Philip II, it is relevant to determine whether his decision was appropriate from an economic and social point of view. This insight is essential, not only for a fair assessment of the historical figure but also to glimpse the opinion that his contemporaries might have had of his decisions.

The geographic decisions made by agents are not based on the reality of the territory but on the vision each of them has of it or, in other words, based on their personal mental maps (Gould & White, 1986). Today we do not pay too much attention to this question because modern cartographic advances have brought our vision of the world very close to reality. However, this was not the situation in the sixteenth century, so if we want to assess the decision to choose Madrid as the capital without falling into anachronism (Fischer, 1970), we must determine precisely the mental map that Philip II had of Spain, especially the location of the cities and the roads that connected them. This is, in this case, a particularly relevant question since, in the sixteenth century, the cartographic representation of the Iberian Peninsula was undergoing a profound process of improvement, in which Ptolemaic maps coexisted with other more modern ones with very different planimetries. The recreation of this mental map is the objective of the work presented here, which is structured according to the following scheme.

In the materials and methods section, first, the distorting effect that the deficiencies in the cartography of the time produced in Philip II's vision of the territory are evaluated. Secondly, the other sources of geographic information that also influenced the formation of the monarch's mental map and its limitations are pointed out. Finally, in third place, an approximate method is proposed to recreate the network of roads in Spain in the second half of the sixteenth century and the vision that the elites of the time had of it.

2. Materials and methods

To determine the extent to which the limitations of the time's cartography may have affected the decision on the choice of the capital, we must establish which maps were used..

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Cartometric analysis of selected works by Leonardo da Vinci

Abstract. This research presents the results of the cartometric analysis of two Leonardo da Vinci's works, i.e. the *Mapa mundi* and *A map of Imola*. The analysis of the *Mapa mundi* was conducted by employing various distortion measures and creating maps to show their distribution by distortion isograms. *A map of Imola* was analysed utilising MapAnalyst, taking advantage of the software's tools, such as distortion grids, isolines of scale and local map rotation angles.

Keywords: Leonardo da Vinci, Imola town map, world map, cartographic projection, cartometric properties

1. Introduction

Leonardo da Vinci (1452–1519) lived and worked in the Renaissance, which was a period of great discoveries and progress in science, technology, and art. This period was characterised by a significant progress in cartography, to which Leonardo also made a contribution. The most well-known cartographic works by Leonardo da Vinci include: *A map of Imola*, the map of the Chiana Valley, map of western Tuscany, the map of the Pontine Marshes and the *Mapa mundi*. Apart from these works, he also created numerous other maps and topographic sketches, mainly for military, hydrological, and engineering purposes. The cartographic works of Leonardo da Vinci were described in several publications, including Isaacson (2017), Kemp (2007), Puceković (2013), Ristujczina (2020), Snyder (1993), and Tyler (2017).

The paper presents the results of the cartometric analysis of the Leonardo da Vinci's *Mapa mundi* and *A map of Imola*. These works were selected due to the availability of modern analytical methodologies and software that support such analysis. Although Leonardo da Vinci did not provide mathematical functions describing the projection he used for the *Mappa mundi*, they were introduced later, e.g. in Bower (2012). The projection functions provide a basis for conducting a detailed analysis of a projection taking advantage of modern methods and computer software. On the other hand, *A map of Imola* has a geometric basis. It was created according to detailed field measurements, so its cartometric properties can be defined. The analysis of the map is limited only to the area inside the city walls. As the applied methods and software require the identification of the corresponding points on the historical map and on an equivalent contemporary map, it would be difficult to identify such points outside this area. Other maps created by Leonardo da Vinci cover large areas drawn from a bird's eye view, which were not based on such precise measurements as the map of Imola.

A map of Imola (Figure 1) was drawn in 1502. As opposed to most town maps from this era, which were made using oblique projection, *A map of Imola* employed the orthogonal projection. The author measured the length of streets using steps. The directions were measured

Landmark Base Point Approach to Positional Accuracy Analysis for Historical Geographic Map Applications Before WWI: A case study 1914 German Blue and 1836 Moltke about in Historical Peninsula of Istanbul

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Research Article

Keywords: German Blue map, Moltke map, Istanbul historical peninsula, Helmert, Affine, Huber loss

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Abstract

Thanks to advances in current technology and computer software, mathematical computations and engineering applications that used to require hours or even days can now be performed quickly. Cartography, unquestionably one of the world's oldest branches of scientific study, is among the fields that have been most influenced by technological improvements. These improvements have enhanced interest in historical maps while also paving the way for modern mapping. All of this process has created new topics of study for cartographers. Also, it is possible to examine old maps using the Map Analyst software which can enable the investigation of time dependent changes. Helmert, Affine and Huber loss function as robust estimation method were analysed. Thanks to the distortion grids, it can be observed in which region the movement is denser. In this study, by using 29 absolute tie points, the old Istanbul maps (the German Blue maps produced in 1913-1914 and the Moltke maps produced in 1836-1837) were compared with the new maps. Additionally, it is aimed to observe the change in the field of cartography with the opportunities offered by the latest software and to provide support to reliable data. It has been observed that a comparison can be made by using the points on the historical maps of Istanbul with the corresponding points on a new contemporary map.

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Article

Using Historical Maps within a GIS to Analyze Two Centuries of Rural Landscape Changes in Southern Italy

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Abstract: The current characteristics of a rural landscape may be better understood if suitable information related to its past is available. The availability of a Geographical Information System (GIS) can enable the analysis of landscape features in relation to several aspects, e.g., the evolution and mutual inter-relation among different ecosystems, the impact and sustainability of human activities, the visual characteristics of a landscape, etc. The analysis of geographical information, derived from historical maps, within a GIS could, therefore, prove to be a very powerful tool, for a better-informed decision-making and management of a rural landscape. With the aim to identify the land use changes in a rural area located in the Basilicata Region (Southern Italy), a territorial analysis was conducted through a GIS, in which data taken from historical maps—covering a period of 184 years, from 1829 to 2013—were implemented. Three-dimensional reconstruction of the rural landscape during different periods were obtained through digital terrain models (DTM). The land cover changes were also evaluated, demonstrating how they have affected the quality of the forest ecosystem in the area. The final results that were obtained comparing historical documents and current maps enabled the evaluation of the multi-temporal, morphological, and vegetation variations in this rural landscape. The analysis that was conducted has great potential for assessing and monitoring landscape diversity and typical changes of vegetation, even in different geographical locations, where appropriate interventions in landscape structures may be so planned.

Keywords: geographical information system; historical maps; landscape changes; rural land

1. Introduction

During the last decades, changes in land use and management have led to the degradation of several cultural landscapes in rural areas, mostly in those located in the Eastern Mediterranean, with relevant consequences for local populations, landscape functionality, and the maintenance of ecosystem services [1]. The analysis of rural land modifications, as well as the wider environment and landscape context in which they take place, is important in order to understand the profound transformations connected with human intervention and natural events [2,3].

The digitization of historical cartography allows for understanding the evolution of the landscape over time, and may account for the susceptibility of spaces to territorial transformations and provide insights to spatial and contextual specifics, which is an issue that is essential for appropriate spatial planning [4]. With the support of a GIS in which historical documents are input, a multi-temporal analysis of land is possible. This is a fundamental tool for monitoring landscape diversity and changes in vegetation and landscape structure [5–7].

Visibility analysis may serve as the starting point to evaluate the quality, fragility, and aptitude for the protection of the area's biophysical units. This analysis has a two-fold importance:

THE RIJKS
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BULLETIN

On the Thresholds of an Old Map: A Paracartographic Approach to Joost Jansz Bilhamer's *Caerte van Noorthollant*

• ANNE-RIEKE VAN SCHAIK AND BRAM VANNIEUWENHUYZE* •

The Rijksmuseum's Print Room collection holds more than 14,000 old maps.[1] Many users – historians, archaeologists, art historians, archivists, curators, collectors, map lovers and more – are curious about what these old maps show ('what was where?') and how accurately that information is depicted. They are usually looking for quite specific information, for example where a particular house was located, how a road ran previously, or where a particular place-name was situated. The old map is then consulted because of its documentary value and it effectively tells the researcher what the landscape and society looked like in the past, at least insofar as it is accurate and reliable. Depending on this, the old map is seen as proof *à charge* or *à décharge*.[2] For this reason scholars frequently question and study the accuracy, reliability and evidential value of old maps.[3] Old maps also often serve as illustrations in books, magazines, exhibitions, websites, presentations and the like. Their illustrative and aesthetic values are paramount, other aspects are usually ignored. Viewers do sometimes get some metadata – in a caption or on a wall text in an exhibition – but otherwise they are presented in a vacuum.

The documentary and illustrative values of an old map are important, but not in themselves sufficient if we want to determine a map's importance.

< *detail fig. 1*

Other aspects and questions are at least as interesting or relevant: What was the production process? What were the intentions of the clients, cartographers and map publishers? How was the map used in the past, by whom and why? And what values did people attach to it, both in their own time and afterwards? These are questions about the socio-cultural significance and reception of old maps that cannot be easily or directly 'read' from a map. Some creativity is consequently needed to answer them. In this article we propose to adopt the 'paracartographic approach', which provides tools to better place an old map in its historical context and focus on less obvious aspects and questions in the research of historical cartography.[4]

In what follows we begin by explaining the principles of the paracartographic approach. We then demonstrate how this approach can be put into practice by applying it to a specific map: the *Caerte van Noorthollant*, made by Joost Jansz Bilhamer (c. 1521-1590) in 1575 and republished in 1608 by Herman Allertsz Koster (c. 1573-after 1646), part of the Rijksmuseum's Print Room collection (fig. 1). This choice was carefully considered: it concerns a well-known, fairly complex and sufficiently studied map.[5] Moreover, Bilhamer's map is a typical product of the commercial cartography that

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F. APOYO

F.1. DINAMICA EGO

CG9. F1

1. Descripción

Dinamica EGO consiste en una plataforma sofisticada para el modelado ambiental con grandes posibilidades para el diseño, desde un modelo espacial estático muy simple hasta modelos dinámicos muy complejos.

El entorno del software, escrito en lenguaje C++ y Java, contiene una serie de algoritmos que han llamado “functors”. Cada uno de ellos realiza una operación diferente. Los desarrolladores del programa han implementado algunos de los algoritmos de análisis espacial disponibles en los Sistemas de Información Geográfica (SIG) comerciales. Además, cuenta con una serie adicional de algoritmos diseñados para simulaciones espaciales como funciones de transición y métodos de calibración y validación.

Los “functors” han sido secuenciados en forma de gráfico para establecer, de este modo, un flujo de datos visuales. Con la interfaz gráfica del programa se pueden crear modelos arrastrando y conectando “functors” a través de sus puertos de manera muy simple. Cada uno de los puertos representa un conector a un elemento de datos como un mapa, una tabla, una matriz, una expresión matemática o una constante. Por lo tanto, los modelos se pueden diseñar como un diagrama cuya ejecución sigue una cadena de flujo de datos.

En resumen, Dinamica EGO favorece la simplicidad, la flexibilidad y el rendimiento, optimizando la velocidad y los recursos de la computadora, como la memoria y el procesamiento paralelo.

Dinamica EGO está construido por un equipo de desarrolladores de software y científicos del *Centro de Sensoramiento Remoto da Universidade*

Federal de Minas Gerais (CRS/UFMG), Brasil. Su objetivo es crear herramientas y métodos para aplicar a una gran variedad de estudios de dinámica de paisajes y modelado ambiental y, además, diseminar esta tecnología libremente a estudiantes e investigadores interesados en sus aplicaciones.

Este software se ha usado recientemente en los trabajos de Campos et al., 2022; Dutra et al., 2022; Latorre-Cárdenas et al., 2023; Marques-Carvalho et al., 2022; Ullo-Espíndola et al., 2021 y Vaissière et al., 2021.

2. Características técnicas

Programa	Dinamica EGO		
Versión	7.6.0	Año	2023
Tipología	Geoestadística		
Capacidades del programa	Plataforma para el modelado ambiental desde el modelo espacial estático hasta dinámicas muy complejas. Posee una serie de algoritmos espaciales complejos para el análisis y la simulación de fenómenos espacio-temporales. El programa permite emplear libremente una combinación de álgebra de mapas, técnicas de autómatas celulares y manipulación de datos y tablas para representar sistemas socioeconómicos y ambientales complejos, sin estar limitados al uso de modelos predefinidos		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Freeware Propietario (CRS/UFMG)
Desarrollador	Centro de Sensoramiento Remoto da Universidade Federal de Minas Gerais (CRS/UFMG)		
Web	https://csr.ufmg.br/dinamica/		

3. Ejemplos de trabajos científicos

land

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Article

Spatial Dynamic Models for Assessing the Impact of Public Policies: The Case of Unified Educational Centers in the Periphery of São Paulo City

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Abstract: Cities continuously evolve and dynamically organize themselves in unbalanced ways and by means of complex processes. Efforts to minimize or solve the problems resulting from spatial inequalities tend to fail when relying on traditional public policies. This work is committed to analyzing the context for implementing public policies and their impacts on the periphery of São Paulo, Brazil. São Paulo is a city characterized by territorial and social heterogeneity and inequality. The materialization of these public policies involves the construction of unified educational centers in peripheral neighborhoods that, in addition to education, offer sports, leisure, and entertainment activities not only to enrolled students but to the wider residents' community. The adopted methodology was based on cellular automata models driven by remotely sensed images designed to investigate land use and land cover patterns in the surroundings of these educational centers before and after their construction. The achieved results demonstrate that the initial land use and land cover configurations have a great influence on the land use and land cover spatial arrangements after the construction of the educational centers. However, in all the test sites of this research, it was observed that these social infrastructure facilities favored the reproduction of real estate market logic, marked by socially exclusive differentiation and an uneven appreciation of the urban environment.

Keywords: urban public policies; spatiotemporal models; urban land use and land cover change; cellular automata

Citation: Campos, P.B.R.; Almeida, C.M.d.; Queiroz, A.P.d. Spatial Dynamic Models for Assessing the Impact of Public Policies: The Case of Unified Educational Centers in the Periphery of São Paulo City. *Land* **2022**, *11*, 922. https://doi.org/10.3390/land11060922

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1. Introduction

According to a recent UN report, urban areas are expected to absorb virtually all the future growth of the world's population. While 55% of the world's population lives in urban areas today, this proportion is expected to increase to 68% by 2050 [1]. The urban population is unevenly distributed worldwide, and there is a massive concentration of people in highly urbanized areas, especially in megacities, which are those that shelter at least 10 million people. Nowadays, there are 33 megacities in the world, which accounted for 13% of the world's urban population in 2018, with Latin America leading the charge in this respect with 18% of its urban population residing in megacities [2].

Although megacities are notable for their size, concentration of economic activities, and active role in the global economy [2], they are usually characterized by severe socioeconomic and spatial inequalities, especially in developing countries. According to [3], a very common situation in most large cities of Latin America is speculation and increased urbanization costs in which the price of land forces the low-income sectors to overcrowd in central areas or to do without basic services in the city surroundings. This argument is supported by [4]. They also stated that, in the urban land market, higher-income groups can outbid lower-income ones for more desirable sites, which are those with access to opportunities and natural amenities, relegating the needy population to squatter settlements

fire

MDPI

Article

Fire Dynamics in an Emerging Deforestation Frontier in Southwestern Amazonia, Brazil

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Abstract: Land management and deforestation in tropical regions cause wildfires and forest degradation, leading to a loss of ecosystem services and global climate regulation. The objective of the study was to provide a comprehensive assessment of the spatial extent and patterns of burned areas in a new deforestation frontier in the Amazonas state. The methodology applied cross-referenced burned area data from 2003 to 2019 with climate, land cover, private properties and Protected Areas information and performed a series of statistical tests. The influence of the Multivariate ENSO Index (MEI) contributed to a decreasing rainfall anomalies trend and increasing temperature anomalies trend. This process intensified the dry season and increased the extent of annual natural vegetation affected by fires, reaching a peak of 681 km^2 in 2019. The results showed that the increased deforestation trend occurred mostly in public lands, mainly after the new forest code, leading to an increase in fires from 66 to 84% in 2019. The methods developed here could identify fire extent, trends, and relationship with land cover change and climate, thus pointing to priority areas for preservation. The conclusion presented that policy decisions affecting the Amazon Forest must include estimates of fire risk and impact under current and projected future climates.

Keywords: forest fires; burned area; remote sensing; Amazon; tropical forest; public policy

Citation: Dutra, D.J.; Anderson, L.O.; Fearnside, P.M.; Graça, P.M.L.d.A.; Yanai, A.M.; Dalagnol, R.; Burton, C.; Jones, C.; Betts, R.; Aragão, L.E.O.e.C.d. Fire Dynamics in an Emerging Deforestation Frontier in Southwestern Amazonia, Brazil. *Fire* **2023**, *6*, 2. https://doi.org/10.3390/fire6010002

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1. Introduction

Forests are important global climate regulators and provide essential environmental services, also known as "regulating" ecosystem services. The Amazon Forest is the largest tropical forest in the world and plays an important role in global climate regulation through both its stock of carbon and its provision of water vapor that is critical to rainfall in wide areas of South America [1]. Amazon forest fires can impact vegetation integrity and biodiversity [2–5], resulting in changes in the forest hydrological functions [6] and carbon storage [7–13]. Forest fire also causes economic losses and human respiratory diseases [14–17], and the cost of controlling fire with field brigades and aircraft is extremely high [18,19].

Natural fires in the Amazon Forest are rare events with return intervals of hundreds to thousands of years [20]. However, direct human impacts and climate change are greatly increasing the frequency and scale of forest fires in humid forests that were traditionally considered resistant to fire [8,21–24]. It is estimated that 58% of the Amazon is currently

land

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Article

Estimating Fragmentation and Connectivity Patterns of the Temperate Forest in an Avocado-Dominated Landscape to Propose Conservation Strategies

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Abstract: The rapid expansion of avocado cultivation in Michoacán, Mexico, is one of the drivers of deforestation. We assessed the degree of fragmentation and functional connectivity of the remaining temperate forest within the Avocado Belt and prioritized patches that contribute the most to connectivity using a network-based approach and modelling different seed and pollen dispersal scenarios, including two types of patch attributes (size and degree of conservation). As landscape transformation in the region is rapid and ongoing, we updated the land-use and land-cover maps through a supervised classification of Sentinel-2 imagery, improving the reliability of our analyses. Temperate forest is highly fragmented within the region: most patches are small (<30 ha), have a reduced core-area (28%), and irregular shapes. The degree of connectivity is very low (0.06), dropping to 0.019 when the degree of conservation of patches was considered. The top 100 ranked patches of forest that support the connectivity of seeds and pollen have different characteristics (i.e., size and topology) that may be considered for implementing conservation and management strategies. Seed dispersal seems to be more threatened by fragmentation than pollen dispersal, and patches that are important for maintaining seed connectivity are embedded in the denser zone of avocado orchards.

Keywords: structural and functional connectivity; habitat-quality; degree of connectivity; supervised classification; seed and pollen dispersal

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Citation: Latorre-Cárdenas, M.C.; González-Rodríguez, A.; Godínez-Gómez, O.; Arima, E.Y.; Young, K.R.; Denvir, A.; García-Oliva, F.; Ghilardi, A. Estimating Fragmentation and Connectivity Patterns of the Temperate Forest in an Avocado-Dominated Landscape to Propose Conservation Strategies. *Land* **2023**, *12*, 631. https://doi.org/10.3390/land12030631

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1. Introduction

Temperate forests constitute the majority of the forest ecosystems in the northern hemisphere and play an important role in supporting ecological processes and nature's contributions to people worldwide [1,2]. In Mexico, temperate forests include pine, oak, pine-oak, and oyamel forests, occupy a large part of the country, nearly 17.4% (340,000 km^2; [3]), maintain a high biodiversity of native plants and animals [4–6], and provide fundamental ecosystem services, such as nearly 80–90% of timber production in the country [7] and about 54% of the carbon sequestration and 25% of the water infiltration [8–10].

Mexico is one of the centers of the diversification of pines (*Pinus*, Pinaceae; [11]) and oaks (*Quercus*, Fagaceae; [12]), harboring 46 of 110 pine taxa and 160 of about 450 oak species that have been described worldwide [4,13,14]. Despite the invaluable biological heritage and the ecological importance of temperate forests for Mexico, these forests have been lost at an annual rate of 0.5–0.8%, mainly due to changes in land use, increased fires, and illegal logging [5,6,13]. In the state of Michoacán, deforestation has led to the loss of up

remote sensing

MDPI

Article

Simulation and Prediction of Urban Land Use Change Considering Multiple Classes and Transitions by Means of Random Change Allocation Algorithms

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Abstract: The great majority of the world population resides nowadays in urban areas. Understanding their physical and social structure, and especially their urban land use pattern dynamics throughout time, becomes crucial for successful, effective management of such areas. This study is committed to simulate and predict urban land use change in a pilot city belonging to the São Paulo Metropolitan Region, southeast of Brazil, by means of a cellular automata model associated with the Markov chain. This model is driven by data derived from orbital and airborne remotely sensed images and is parameterized by the Bayesian weights of evidence method. Several layers related to infrastructure and biophysical aspects of the pilot city, São Caetano do Sul, were used as evidence in the simulation process. Alternative non-stationary scenarios were generated for the short-run, and the results obtained from past simulations were statistically validated using a multiresolution "goodness-of-fit" metric relying on fuzzy logic. The best simulations reached fuzzy similarity indices around 0.25–0.58 for small neighborhood windows when an exponential decay approach was employed for the analysis, and approximately 0.65–0.95 when a constant decay and larger windows were considered. The adopted Bayesian inference method proved to be a good parameterization approach for simulating processes of urban land use change involving multiple classes and transitions.

Keywords: orbital images; digital terrain model; Google Earth; cellular automata (CA)

Citation: Marques-Carvalho, R.; Almeida, C.M.d.; Escobar-Silva, E.V.; Oliveira Alves, R.B.d.; Anjos Lacerda, C.S.d. Simulation and Prediction of Urban Land Use Change Considering Multiple Classes and Transitions by Means of Random Change Allocation Algorithms. *Remote Sens.* **2023**, *15*, 90. https://doi.org/10.3390/rs15010090

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1. Introduction

The percentage of the population living in urban areas has been increasing since the 1950s on all continents. On average, the global population has become predominantly urban since 2008. However, data from the World Urbanization Prospects—The 2018 Revision—show that some geographic regions, such as Africa, will only be affected by this change in future decades, unlike Latin America and the Caribbean, for example, which have been predominantly urban since the 1960s [1]. In accordance with the behavior observed in Latin America, Brazil had its land use converted to primarily urban in the last century. Around the mid-1960s, the urban population exceeded the rural one and has kept growing ever since, reaching 84.4% in 2010 [2]. In that same year, the southeastern region registered an urban population of 92.9%, the highest among all the others. By 2050, it is expected that 92.4% of the Brazilian population will live in urban areas, a percentage above that projected for all Latin America and the Caribbean, which will remain below 90% on average [3].

Understanding the physical and social structure of cities, and particularly their land use pattern dynamics throughout time, becomes crucial for successful, effective management of such areas. As stated by [4], the success of the majority of mankind's undertakings depends on a sound governance of their financial, institutional, and especially physical

sustainability

MDPI

Article

Simulation and Analysis of Land Use Changes Applying Cellular Automata in the South of Quito and the Machachi Valley, Province of Pichincha, Ecuador

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Abstract: Rapid urban growth has historically led to changes in land use patterns and the degradation of natural resources and the urban environment. Uncontrolled growth of urban areas in the city of Quito has continued to the present day since 1960s, aggravated by illegal or irregular new settlements. The main objective of this paper is to generate spatial predictions of these types of urban settlements and land use changes in 2023, 2028 and 2038, applying the Dinamica EGO cellular automata and multivariable software. The study area was the Machachi Valley between the south of the city of Quito and the rural localities of Alóag and Machachi. The results demonstrate the accuracy of the model and its applicability, thanks to the use of 15 social, physical and climate predictors and the validation process. The analysis of the land use changes throughout the study area shows that urban land use will undergo the greatest net increase. Growth in the south of Quito is predicted to increase by as much as 35% between 2018 and 2038 where new highly vulnerable urban settlements can appear. Native forests in the Andes and forest plantations are expected to decline in the study area due to their substitution by shrub vegetation or agriculture and livestock land use. The implementation of policies to control the land market and protect natural areas could help to mitigate the continuous deterioration of urban and forest areas.

Keywords: land use change; cellular automata; Quito; native forest; urban land use; rural land use

Citation: Ulloa-Espíndola, R.; Martín-Fernández, S. Simulation and Analysis of Land Use Changes Applying Cellular Automata in the South of Quito and the Machachi Valley, Province of Pichincha, Ecuador. *Sustainability* **2021**, *13*, 9525. https://doi.org/10.3390/su13179525

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1. Introduction

Human activity has generated land use change for centuries, shaping the territory and exploiting natural resources [1]. One of the uses with the highest impact on ecosystems is urban land use. The task of managing urban growth has increased in both scope and complexity, as today more than half the world's population lives in cities. These cities are expected to absorb 72% of the future growth of the world's population [2] by 2050 [3]. Globally, urban cover is expanding at twice the rate of the global population growth due to rapid urbanization [4]. Urban land use increased from 0.6 million km^2 in 2000 to 0.7–0.9 million km^2 in 2010, with projections of 1.2 million km^2 by 2050 [5]. More than 5.87 million km^2 of land have a positive probability (>0%) of being converted to urban areas by 2030 [4]. Population growth and rural-to-urban migration are the principal drivers of this sharp surge [6].

Although this urban growth represents an important opportunity, according to the Sustainable Development Goals SDG 11, the aim of urban development should be to maximize benefits for the population and make cities inclusive, safe, resilient and sustainable, while minimizing both economic and environmental costs [2,7,8].

However, rapid urban growth has historically led to changes in land-use patterns and the degradation of natural resources and the urban environment. It drives habitat loss [9],

sustainability

MDPI

Article

Modeling Alternative Approaches to the Biodiversity Offsetting of Urban Expansion in the Grenoble Area (France): What Is the Role of Spatial Scales in 'No Net Loss' of Wetland Area and Function?

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Abstract: It is increasingly common for developers to be asked to manage the impacts of their projects on biodiversity by restoring other degraded habitats that are ecologically equivalent to those that are impacted. These measures, called biodiversity offsets, generally aim to achieve 'no net loss' (NNL) of biodiversity. Using spatially-explicit modeling, different options were compared in terms of their performance in offsetting the impacts on wetlands of the planned urban expansion around Grenoble (France). Two implementation models for offsetting were tested: (a) the widespread bespoke permittee-led restoration project model, resulting in a patchwork of restored wetlands, and (b) recently-established aggregated and anticipated "banking" approaches whereby larger sets of adjacent parcels offset the impacts of several projects. Two ecological equivalence methods for sizing offsets were simulated: (a) the historically-prevalent area-based approach and (b) recently introduced approaches whereby offsets are sized to ensure NNL of wetland functions. Simulations showed that a mix of functional methods with minimum area requirements was more likely to achieve NNL of wetland area and function across the study area and within each subwatershed. Our methodology can be used to test the carrying capacity of a landscape to support urban expansion and its associated offsetting in order to formulate more sustainable development plans.

Keywords: mitigation hierarchy; biodiversity offsetting; no net loss; spatially-explicit modeling; wetlands; Isère; European Alps; habitat banking; Dinamica; carrying capacity

1. Introduction

In an increasing number of countries, the mitigation of development impacts on biodiversity and ecosystems includes compensating for any unavoidable impacts through ecological conservation or restoration actions in the field [1]. Ecological compensation should remain the last resort, after all other avoidance and reduction measures have been implemented to minimize the residual impact of a development project on the environment. Developers are required to apply the aforementioned mitigation hierarchy. Biodiversity offsetting is a "specific and rigorously quantified type of compensation measure" [2] (p. 1690) with the stated objective of achieving 'no net loss' (NNL) of biodiversity—in other words, an ecological equivalence between the impacted and the compensated biodiversity.

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Vaissière, A.-C., Quétier, F., Bierry, A. et al. (2021). Modeling Alternative Approaches to the Biodiversity Offsetting of Urban Expansion in the Grenoble Area (France): What Is the Role of Spatial Scales in 'No Net Loss' of Wetland Area and Function? Sustainability. [Online]. 13 (11). p.p. 5951. http://dx.doi.org/10.3390/su13115951

F.2. AQUATOOL+

CG9. F2

1. Descripción

AQUATOOL es un entorno de desarrollo de sistemas de soporte a la decisión (SSD) para planificación y gestión de cuencas o de sistemas de recursos hídricos. Como SSD proporciona recursos para ayudar al análisis de diversos problemas relacionados con la gestión del agua. Además, AQUATOOL es una línea de investigación en continuo desarrollo, por lo que además de las conocidas herramientas de análisis de la gestión de cuencas, también proporciona otras herramientas que facilitan el desarrollo de trabajos relacionados.

Este software surgió para resolver muchos de los problemas que pueden plantearse en el análisis de Sistemas de Recursos Hídricos (SRH) desde el punto de vista de la planificación y de la gestión de SRH.

Los primeros antecedentes del programa se remontan a 1982 cuando en el Departamento de Ingeniería Hidráulica y Medio Ambiente de la Universidad Politécnica de Valencia desarrolló el módulo USOCON de simulación de la gestión de una cuenca. En 1987 se desarrolló el módulo Optired con el que se generaliza la resolución del problema de la asignación del agua mediante la generación de una red de flujo y el uso de algoritmos de programación lineal para largos periodos de tiempo. En 1991 se utilizan estos dos módulos conjuntamente junto con el desarrollo de nuevas aplicaciones para aumentar las posibilidades de análisis, a este conjunto se le denominó AQUATOOL definitivamente.

AQUATOOL se ha empleado en múltiples demarcaciones hidrográficas españolas e internacionales, dando cumplimiento a normas relacionadas con la gestión de los recursos hídricos como la Directiva Marco del Agua (DMA) y han previsto las futuras necesidades que iban a surgir para el desarrollo de los nuevos Planes Hidrológicos.

Las principales investigaciones en las que se ha usado AQUATOOL recientemente son Gil-García et al., 2023; Pardo-Loaiza et al., 2022; Pardo-Loaiza et al., 2021; Rubio-Martin et al., 2023; Sapino et al., 2023; Sondermann y Oliveira, 2022 y Valenzuela-Mahecha et al., 2022.

2. Características técnicas

Programa	AQUATOOL+		
Versión	6.7.16	Año	2023
Tipología	Sistema de soporte a la decisión		
Capacidades del programa	AQUATOOL+ es un entorno de desarrollo de sistemas de soporte a la decisión (SSD) para planificación y gestión de cuencas o sistemas de recursos hídricos. Como SSD proporciona recursos para ayudar al análisis de diversos problemas relacionados con la gestión del agua. Además, este software está en continuo desarrollo en temáticas como el análisis de gestión de cuencas proporcionando otras herramientas útiles. AQUATOOL está siendo empleado por otras instituciones para el desarrollo de herramientas propias con procesos enlazados a otros del propio software.		
Sistema operativo	Windows (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Comercial (gratuito para estudiantes y entidades públicas) Propietario (AIRH/UPV)
Desarrollador	Área de Ingeniería de Recursos Hídricos del Instituto de Ingeniería del Agua y Medio Ambiente de la UPV		
Web	https://aquatool.webs.upv.es/aqt/		

3. Ejemplos de trabajos científicos

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Environmental Science and Policy

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To dam or not to dam? Actionable socio-hydrology modeling to inform robust adaptation to water scarcity and water extremes

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ARTICLE INFO

Keywords:
Socio-hydrology
Decision-making
Positive Multi-Attribute Utility Programming
Cega Catchment

ABSTRACT

The contribution of this paper is twofold: 1) it develops a replicable socio-hydrology-inspired model that elicits agents' preferences while accounting for the two-way feedbacks between complex human and water systems; and 2) it integrates the resultant socio-hydrology model into robustness-based frameworks to inform the adoption of policies that show a satisfactory performance under most plausible futures. The socio-hydrology model is used to produce a database representing multiple plausible futures that quantifies uncertainty regarding scenario assumptions under alternative adaptation strategies. Using a robust decision-making framework, the mechanistic outputs from the database of plausible futures are combined with heuristic methods through experts' knowledge and opinion to co-design scenarios, identify vulnerabilities and quantify tradeoffs of proposed strategies, and subjectively propose new scenarios and choose the preferred adaptation strategy. Methods are illustrated with an application to the Cega Catchment in central Spain, one of the few major catchments in central Spain that remains non-regulated, and where the construction of a major dam has been projected. Following a robust decision-making process informed by our socio-hydrology model and involving all key parties to the decision, the status quo strategy (no dam construction) was revealed preferred.

1. Introduction

Growing water scarcity and more frequent and intense extreme weather events threaten to impose substantial damages on farmers, households, industries, and ecosystems in arid and semi-arid basins (UNEP, 2021). Averting these damages will require the coordinated adoption of not only promising technologies and engineering solutions to expand the supply base and reduce vulnerability to water extremes; but also behavioral instruments that limit exposure to extreme events and reallocate available water resources, so as to avoid rebound effects, ensure the sustainability of water ecosystems, and enhance economic outputs (IPCC, 2022). Yet, despite recurrent calls to mainstream behavioral instruments into water resources management (OECD, 2015; UN, 2021; World Bank, 2017), the contribution from engineering- and behavioral-based approaches remains unbalanced: most basins worldwide rely "disproportionately" on gray engineering to address water-related challenges (OECD, 2021), with over 800 000 dams existing worldwide—of which > 60 000 are large dams (International Rivers, 2022).

The biased focus towards gray infrastructures is of growing concern in arid and semi-arid basins, where water economies have already entered a mature phase characterized by inelastic supplies of additional water works and sharply rising incremental costs due to the significant and growing tradeoffs among uses—including environmental ones (Loch et al., 2020a, 2020b). For example, dam construction throughout North-west United States has provided flood protection and significant supplies of low-priced electricity that stimulated economic activity, while contributing to incremental declines of anadromous fish by interfering with upstream/downstream migration, which eventually led to cases of dam removal (Loomis, 2002, 1996). In Spain, the national dam inventory reveals that 15 recently built dams are ineffective towards their intended objectives, mostly irrigation supply, due to decreasing water inflows caused precisely by upstream irrigation expansion (MITECO, 2019). A recent report recommended the decommission of the dams, albeit acknowledging that some of the previous ecological functions may have been irreversibly lost (Ecologistas en Acción, 2018). The issues of dam construction are therefore "not confined anymore to the design, construction and operation of dams

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water

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Article

The Role of Environmental Flows in the Spatial Variation of the Water Exploitation Index

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Abstract: This article presents a novel methodology to assess the spatial and temporal variations of water resources exploitation within regulated river basins. The methodology, which is based on the application of a basin management model to properly assess the consumed and available water, was applied to a case study in the Iberian Peninsula to analyze the effects of environmental flows in the water resources exploitation of all rivers in the basin. It was demonstrated that the river sections in the upper part of the Órbigo River are subjected to lower water stress levels, so that they would be more suitable alternatives to supply new possible water uses. In addition, it was found that, during the summer months, the available water resources in natural regime are more than 1.5, 1.8 and 2.4 times lower than the consumed water in the upper, lower and middle stretches of the Órbigo River, respectively. This reveals the necessity of regulating the water resource to fulfill the water demands of the basin throughout the year. Finally, it was found that increases (decreases) in environmental flows not only lead to reductions (rises) in water availability, but also can induce decreases (increases) in consumed water resources due to lower (greater) water availability. This effect is more significant as water stress levels are higher. The results of this paper highlight the importance and usefulness of basin management models to accurately estimate the spatial variability of the water exploitation index, and the effects of environmental flows on both water availability and consumed water resources. The proposed approach to reduce the spatial scale of the water exploitation index is also helpful to identify the best water sources in river basins to meet future demands and/or higher values of environmental flows.

Keywords: basin management model; environmental flow scenarios; available water; consumed water; WEI+; Órbigo River basin

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1. Introduction

Water scarcity is a matter of concern in society, since although water is considered a renewable resource, it is also a finite resource that cannot be replaced [1]. Water scarcity, which can be defined as a condition where available water resources do not meet demand [2], is estimated to affect around 80% of the world's population [3]. In fact, water scarcity is considered a key driver of migration due to its impact on health and livelihoods, as well as the conflicts it can trigger [4].

Climate change is generating a reduction in naturally available water resources by creating alterations in the hydrological cycle [5–7]. The reduction in water availability induced by climate change leads to a worsening of water quality [8,9], affecting river ecosystems and compromising the future sustainability of water resources. Therefore, the impact of climate change on socioeconomic activities and the environment represents an aggravating factor of the problem of water scarcity [10–12]. In addition, the projected growth of the world population [13] will imply a greater demand for food in the future and, consequently, a greater use of water in agriculture [14].

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Article

Improving Indicators of Hydrological Alteration in Regulated and Complex Water Resources Systems: A Case Study in the Duero River Basin

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Abstract: Assessing the health of hydrological systems is vital for the conservation of river ecosystems. The indicators of hydrologic alteration are among the most widely used parameters. They have been traditionally assessed at the scale of river reaches. However, the use of such indicators at the basin scale is relevant for water resource management since there is an urgent need to meet environmental objectives to mitigate the effects of present and future climatic conditions. This work proposes a methodology to estimate the indicators of hydrological alteration at the basin scale in regulated systems based on simulations with a water allocation model. The methodology is illustrated through a case study in the Iberian Peninsula (the Duero River basin), where different minimum flow scenarios were defined, assessing their effects on both the hydrological alteration and the demand guarantees. The results indicate that it is possible to improve the hydrological status of some subsystems of the basin without affecting the water demand supplies. Thus, the methodology presented in this work will help decision makers to optimize water management while improving the hydrological status of the river basins.

Keywords: hydrological alteration; hydrological indicators; environmental flow; demand guarantees; water allocation model; Duero River basin

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1. Introduction

A healthy river is a logical consequence of scientific principles, legal mandates and changing social values [1]. Nevertheless, this concept can be treated differently according to the type of water user. From an ecological perspective, a healthy river can sustain its functions and structure despite the anthropogenic influence [2]. Therefore, it is reasonable to think that even if not all of the system variables are identified, the conservation of a sustainable flow regime is enough of a guarantee of a good ecological condition, assuming that there are adequate physicochemical water parameters.

The population necessity for freshwater has led to an increasing number of dams around the world, thus affecting natural flows. The inclusion of the environmental flow concept has encouraged more ecologically informed water management [3]. A well-defined environmental flow must consider numerous variables to establish the river flow regimes. Flow velocities, flooding and scarcity periods characterize the riverine and freshwater ecosystems. The hierarchy of the flow regimes has been properly established in the formulation of the natural flow regime paradigm [4].

The need to measure the flow regime has led to produce more than 200 methods grouped into four main categories: hydrological rules, hydraulic rating methods, habitat simulation methods and holistic methodologies [5]. The indicators of hydrological alteration (IHA) are among the most widely used metrics to estimate the hydrological alteration in river reaches [6,7]. This methodology considers the definition of a series of relevant

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Climate services for water utilities: Lessons learnt from the case of the urban water supply to Valencia, Spain

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ARTICLE INFO

Keywords:
Climate services
Vulnerability assessment
Climate adaptation
Water utility
Climate projections
Water supply
Mediterranean water resources
Resilient cities

ABSTRACT

Climate change projections in many regions of the world show a critical reduction in precipitation and a significant rise in temperatures in the next decades. This change may affect the operation of water utilities in arid and semi-arid parts of the globe. The Mediterranean region is particularly vulnerable to the impacts of climate change on water resources. In this paper, we reflect on the challenges that the water utility sector may experience during the upcoming decades to continue providing its essential service under the new climate scenario. Our reasoning is based on the lessons learned during the co-creation of a climate service with the water utility company of Valencia (Spain) within the framework of the EU ERA4CS project INNOVA. The joint vision of climate, water management researchers and water utility operators resulted in a multi-scale framework for evaluating the vulnerability of the water utility to climate change. The modelling framework couples water quantity and quality and their interaction in a chain of models. The proposed framework forced all parties to consider the issue of the temporal and spatial scales, and the importance of choosing and defining the boundaries of the problem. The analytical framework has three distinct elements: (1) a combination of climate projections; (2) hydrological and water resource management model of the river basin system; (3) reservoir management and water quality model. Two Representative Concentration Pathways (RCP) 4.5 and 8.5 were considered in two timeframes for the analysis: the short term (2020–2040) and the medium term (2041–2069). The results show a significant reduction in water availability combined with an increased frequency and intensity of phytoplankton blooms and anoxia episodes. These changes result in the deterioration of the reservoir trophic state, shifting from ultraoligotrophic-oligotrophic (control period) to oligotrophic-mesotrophic (RCP 8.5). The example shows how the combination of models on different scales and the involvement of experts in the co-creation process can result in a customized climate service that provides valuable information to water utility operators that can be used to reduce the system's vulnerability to climate change.

Practical implications

- The water utility sector provides an essential service to the society and plays a vital role in economic development. The resilient adaptation of water utilities to the new climate and global scenario is a critical task that requires the cooperation of utility operators, water managers and climate scientists. This article explores the challenge of co-creating a climate service to assess the water utility's vulnerability to climate change in Valencia, Spain. The study takes into account multiple spatial scales (regional, river basin, and reservoir) and a combination of climate scenarios. The presented results are based on the ERA4CS project INNOVA, where several climate services were created by connecting the private, public and knowledge communities.
- The co-creation of the climate service for Valencia's water utility required close collaboration between the research team from the Universitat Politècnica de València and the managers from the water utility company Global Omnium. A chain of models was designed, validated and developed, consisting of 1)

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Research papers

A multi-agent cellular automata model to explore water trading potential under information transaction costs

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ARTICLE INFO

Keywords:
Mathematical Programming Model (MPM)
Agent-based model (ABM)
Water markets
Transaction costs
Socio-hydrology

ABSTRACT

The economic literature has extensively researched water markets, finding that this instrument can deliver superior resource allocations under growing scarcity. However, these assessments typically ignore the information, bargaining, and enforcement costs that occur in trades, known as transaction costs, which can be particularly relevant in emerging markets such as those for water. This paper presents a multi-agent cellular automata model that couples a positive multi-attribute utility programming (PMAUP) model with an agent-based model (ABM) to elicit the information transaction costs of water trading under alternative market and climate scenarios. A first experiment evaluates an ideal water market with no transaction costs, which is then compared to alternative decentralized spot market setups representing different degrees of information availability that are modeled using the coupled PMAUP-ABM. The difference between the economic surplus under the ideal market and that achieved under alternative market setups with information constraints is used as a proxy value of information transaction costs. Methods are illustrated with an application to the Douro River Basin in central Spain. Results show that information transaction costs can reduce the economic surplus between 0.6% and 45% depending on the scenario.

1. Introduction

Farming accounts for approximately 70 % of water withdrawals in the world today, while often constituting the marginal (i.e. least productive) uses of freshwater resources (FAO, 2021). In a context of growing scarcity, water markets can support the reallocation of water towards agricultural uses with higher added value, hence offering an opportunity to enhance economic growth and social welfare without increasing demand (Damania et al., 2017). Agricultural and behavioral economics research has developed increasingly sophisticated empirical models to elicit agent's preferences and reveal market equilibria through demand–supply interaction, including programming models (Graveline, 2016), econometrics (Zuo et al., 2015), Data Envelopment Analysis (Frija et al., 2011), hedonic pricing (Faux and Perry, 1999) and contingent valuation (Storm et al., 2011); of which the former is the most commonly used approach. Most of these models suggest a promising performance of water markets, which are expected to significantly increase the efficiency in water resources use (Wheeler, 2021). Yet, despite relevant methodological and empirical advances in the application of behavioral economics methods and techniques, the assumption of zero Transaction Costs (TCs) remains a major limitation in achieving realistic estimates of the economic performance of water markets.

TCs can be broadly defined as "the costs of arranging a contract *ex-ante*, and then monitoring and enforcing it *ex-post*, as opposed to the more conventional reallocation costs which are the costs of executing the contract [i.e. the foregone income, or the monetized utility loss, of the seller]" (Matthews, 1986). Broadly speaking, we can divide TCs into two macro-categories: private and institutional TCs. Private TCs are the ones concerning the traders, while the institutional ones refer to the creation of the market. Institutional TCs can be considered a one-time component (Deng et al., 2018), and therefore independent from single transactions, while the private TCs are directly connected to market exchanges. Loch et al., (2018) define private TCs as the sum of the following elements: "i) time invested in monitoring market activity and

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water

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Article

Climate Adaptation Needs to Reduce Water Scarcity Vulnerability in the Tagus River Basin

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Abstract: In southern Europe, climate change is expected to aggravate water scarcity conditions and challenge current water management practices. The present paper evaluates the impacts of climate change in the highly regulated Tagus River basin and assesses various adaptation options, quantifying the effort needed to maintain the ability to sustain current water uses. A water management and allocation model covering surface and groundwater resources is used to evaluate available and renewable water resources for different climate scenarios. Additionally, the Water Exploitation Index Plus (WEI+) and water supply reliability criteria are used to quantify water scarcity and the ability to satisfy water demands, respectively. The results show that climate change will significantly change the stream flow regime and reduce water availability in the Tagus River basin, but the existing reservoir infrastructure will alleviate some of these impacts, especially in the dry half-year. Until the end of the century, water scarcity levels, measured by annual WEI+, are expected to increase in the Tagus River basin from 0.46 to 0.52 or 0.62, respectively under two Representative Concentration Pathways (RCP 4.5 or RCP 8.5). The benefits of streamflow regulation vary with the hydrological regimen, the current degree of water use and the role of groundwater resources to meet demand. The benefits of streamflow regulation are also dependent on the environmental flow requirements that will be adopted in the future. A reduction of water consumption for irrigation by 25% to 40% will significantly improve the Tagus River system performance and maintain the current scarcity situation in the future, under the expected scenarios of climate change.

Keywords: climate change; adaptation measures; water availability; water demand reduction; transboundary river basin

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1. Introduction

Over the last decades, significant hydrological alterations have been occurring worldwide due to changes in precipitation and temperature patterns and to the intensification of the frequency and severity of extreme climatological conditions (floods and droughts) [1–5]. In Southern Europe, climate projections indicate increasing drier conditions and a higher frequency of droughts which will add further challenges to a region already exposed to water scarcity and frequent drought events [6–8]. Associated with increasing human-induced pressures, such as increasing water demands and land-use changes, these climate trends raise serious concerns about the ability to sustain current water uses. In some southern European river basins, where water constrains socio-economic development and the ecological integrity of environmental systems, current climate change projections have serious implications for major policy decisions, quite beyond the sectoral policies for water planning and management, and resource allocation and use [8,9].

To address climate change impacts on water resources and to alleviate the effects of expected water shortages, water management policies must be modified and adapted to future climate conditions, as the adopted global mitigation efforts to control greenhouse gas emissions to the atmosphere are insufficient to completely reverse current climate trends.

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Article

Hydrological Drought-Indexed Insurance for Irrigated Agriculture in a Highly Regulated System

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Abstract: Water scarcity is an increasingly recurring problem for irrigated agriculture in Mediterranean regions. It is, therefore, necessary to establish technical and financial measures to enable irrigators to deal with this problem. This study presents a new index-based drought insurance scheme in an irrigation district in the Jucar river basin in Spain, a highly regulated water system. Three insurance scheme options were evaluated and, the values of the fair risk premiums, the maximum compensation, and the deductible franchise were established. These insurance schemes were designed in agreement with the preexisting drought system operating rules to reduce moral hazard and adverse selection. Risk-reducing and effective evaluation methods were used to determine the insurance coverage's viability for irrigators: standard deviation gross margin, minimum gross margin, and RMSL. The proposed insurances were also evaluated using synthetic hydrological time series generated with a stochastic ARMA model through a basin-wide water resource simulation model developed in the DSS Shell AQUATOOL. Financial indicators, such as the basis risk and claim ratio were applied to analyze the economic feasibility for insurance companies. The results show that a suitable and efficient option is an early-bird contract combined with a trigger of emergency or alert state in a multi-year contract. This type of specialized insurance helps to fill the existing gap in traditional insurance schemes for irrigated crops and offered additional coverage to farmers under drought and water scarcity conditions.

Keywords: hydrological drought; index insurance; irrigation water management; decision support system; Jucar river basin

Citation: Valenzuela-Mahecha, M.A.; Pulido-Velazquez, M.; Macian-Sorribes, H. Hydrological Drought-Indexed Insurance for Irrigated Agriculture in a Highly Regulated System. *Agronomy* **2022**, *12*, 2170. https://doi.org/10.3390/agronomy12092170

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1. Introduction

Irrigated agriculture plays a key role in food production, and therefore, in the food and nutrition security of the world's population [1,2]. With the impact of climate change, the already low profitability of most rainfed crops, as well as their vulnerability to climatic events (drought, heatwaves), will continue to increase the pressure to irrigate more land [3]. Extreme weather events, major biodiversity loss and ecosystem collapse, food crises, water crises, and, the failure of climate change mitigation and adaptation are currently the main global threats [4]. These risks affect the agricultural sector directly since it is not only the productive sector with the highest use and demand for water resources [5] but is also the most exposed to droughts and water scarcity. This makes it necessary to implement production schemes that allow farmers to produce more food while using the minimum amount of water possible. It is also crucial to create risk mitigation strategies that contemplate the technical and economic implications that their implementation would entail.

The agricultural production sector is affected by a variety of drought types: a meteorological drought takes place when there is a continuous shortage of rainfall; agricultural drought is associated with the deficit of moisture in the root zone of a crop in a certain place

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Valenzuela-Mahecha, M.A., Pulido-Velazquez, M. y Macian-Sorribes, H. (2022). Hydrological Drought-Indexed Insurance for Irrigated Agriculture in a Highly Regulated System. Agronomy. [Online]. 12 (9). p.p. 2170. http://dx.doi.org/10.3390/agronomy12092170

F.3. INVEST®

CG9. F3

1. Descripción

InVEST® (Integrated Valuation of Ecosystem Services and Tradeoffs – Valoración Integrada de los Servicios Ecosistémicos y Compesacionales) es una herramienta creada para explorar cómo los cambios en los ecosistemas pueden conducir a cambios en los beneficios que fluyen hacia las personas. Este programa permite crear mapas y valorar los bienes y servicios de la naturaleza que sustentan y satisfacen la vida humana.

Este programa suele usar un enfoque de función de producción para cuantificar y valorar los servicios de los ecosistemas. Una función de producción especifica el resultado de los servicios ecosistémicos proporcionados por el entorno dada su condición y procesos. Una vez que ha sido establecida, podemos cuantificar el impacto de los cambios en la tierra o en el agua sobre los cambios en el nivel de rendimiento del servicio ecosistémico en cuestión.

El conjunto de herramientas de InVEST incluye modelos para cuantificar, mapear y valorar los beneficios proporcionados por los sistemas terrestres, de agua dulce y marinos. Los servicios de InVEST se agrupan en 3 categorías principalmente:

a) Servicios de apoyo, que respaldan a los otros servicios de los ecosistemas, pero no brindan beneficios directamente a las personas.
b) Servicios finales, si proporcionan beneficios directamente a las personas.
c) Herramientas para facilitar los análisis de servicios ecosistémicos.

InVEST es una herramienta de software libre bajo licencia BSD de código abierto. El desarrollo de este software lo realiza *Natural Capital Project* que cada tres meses, aproximadamente, lanza versiones actualizadas del programa. Los modelos InVEST fueron originariamente creados dentro de ArcGIS, pero actualmente los modelos existen de

manera independiente a otro software. La primera versión de este software fue lanzada en 2008.

InVEST es empleado de manera generalizada en el mundo científico y universitario. Recientemente la herramienta ha sido utilizada en los trabajos de Da Silva et al. 2022; Galdino et al. 2023; Li et al. 2023; Li et al. 2020; Ouyang et al. 2022; Wang et al. 2021 y Xu et al. 2023

Se puede consultar una guía de usuario online (en la siguiente página web: https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/es/index.html

2. Características técnicas

Programa	InVEST ®		
Versión	3.14.	Año	2023
Tipología	Gestión de recursos naturales		
Capacidades del programa	InVEST está diseñado para informar las decisiones sobre el manejo de los recursos naturales de un territorio o zona concreta. Proporciona información sobre como de probable es que los cambios en los ecosistemas generen cambios en los flujos de beneficio para las personas. InVEST posee un diseño modular multiservicio que proporciona una herramienta eficaz para explorar los resultados probables de escenarios de gestión y clima alternativos para evaluar las compensaciones entre sectores y servicios. El conjunto de herramientas de InVEST incluye 18 modelos diferentes de servicios ecosistémicos diseñados para ecosistemas terrestres, de agua dulce, marinos y costeros, así como una serie de herramientas auxiliares para ayudar a localizar y procesar datos de entrada y comprender y visualizar los resultados obtenidos.		
Sistema operativo			
	Windows (64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo Apache License 2.0
Desarrollador	Natural Capital Project, 2024. InVEST 3.14.1. Stanford University, University of Minnesota, Chinese Academy of Sciences, The Nature Conservancy, World Wildlife Fund, Stockholm Resilience Centre and the Royal Swedish Academy of Sciences.		
Web	https://naturalcapitalproject.stanford.edu/software/invest		

3. Ejemplos de trabajos científicos

water

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Article

Evaluation of InVEST's Water Ecosystem Service Models in a Brazilian Subtropical Basin

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Abstract: The biophysical modeling of water ecosystem services is crucial to understanding their availability, vulnerabilities, and fluxes. Among the most popular models, the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) models stand out. While many studies have used them, few have assessed their performance. This study evaluates the performance of InVEST's Seasonal Water Yield, Nutrient Delivery Ratio, and Sediment Delivery Ratio models in a subtropical basin in southeastern Brazil on temporal and spatial scales, using 39 years of streamflow data, 29 for total phosphorus and total nitrogen, and 19 for total suspended solids. Statistical indicators R^2, PBIAS, and NSE, were also calculated. The performance of the models varied according to the type of simulated WES and analysis scales used, with the Seasonal Water Yield model demonstrating the best performance and effectively representing the spatial and temporal variability of the average annual streamflow. All models performed well in simulating long-term mean values when compared to observed data. While one should bear in mind the study's limitations, the results indicate that the models perform well in terms of relative magnitude, although their application in studies involving water-resource management and decision making is limited.

Keywords: water ecosystem services; InVEST model; water yield; sediment export; nutrient export

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1. Introduction

A water ecosystem services (WES)-based approach, incorporating an integrated analysis among multiple pressures, ecological statuses, and ecosystem services has been identified as an effective tool to plan and manage water resources, as it links environmental conservation with socioeconomic development [1]. Such an approach enables an assessment of how anthropic activities affect ecosystem composition and functioning, impacting WES, including water supply services for human use, irrigation, and energy generation, as well as regulation services associated with flood mitigation, erosion control, and water purification [2].

A pillar of this approach is biophysical modeling, which quantifies WES from mathematical equations in computational environments [3]. Biophysical models facilitate the understanding of ecohydrological processes in hydrographic basins and the assessment and forecasting of multiple pressures [1]. Well-calibrated, validated models have numerous applications in water management, such as quantifying the effects of land use and climate change [4–6], assessing flood risk [7], and designing and evaluating forest restoration programs [8–11], in addition to generating and transferring historical data for unmonitored basins, which is critical for hydrological studies [12]. Such applications can help formulate and evaluate environmental conservation policies that support sound decision making in water resource management and land-use planning [13].

Over the past few decades, free models to map ecosystem services have emerged [14–16], ranging from simple approaches based on land-use data or habitat-based proxies to complex

Introdução

O InVEST (*Integrated Valuation ofof Environmental Services and Tradeoffs*) é um software livre e de código aberto, desenvolvido por matemáticos, ecólogos, geólogos, economistas, dentre outros especialistas. Ele é resultado de parcerias entre Universidade de Stanford, Universidade de Minnesota, The Nature Conservancy e do World Wildlife Fund (Sharp, 2020).

O InVEST é composto por modelos baseados em estimativas de uma ampla gama de serviços ecossistêmicos relacionados à natureza. Mudanças, em especial no uso das terras, podem afetar os fluxos e valores de serviços ecossistêmicos em uma paisagem terrestre. Os modelos também se prestam aos serviços ambientais de diversos segmentos da sociedade, desde o impacto da mudança de matriz de exploração extrativista (produção de açaí, em vez de palmito, por exemplo) ao estabelecimento de florestas em áreas agrícolas, como as áreas de preservação permanente (APPs) e reservas legais. Garcia e Romeiro (2013) afirmam que as informações geradas pelo InVEST podem fornecer subsídios para uma gestão mais adequada das bacias hidrográficas e contribuir para a implementação de esquemas de pagamento por serviços ambientais (PSA), uma vez que permitem identificar as áreas provedoras e beneficiadas pelos serviços ecossistêmicos.

Nesse contexto, o InVEST é uma ferramenta modular independente. Isso significa que é possível modelar um determinado serviço ecossistêmico específico sem necessariamente fazer uso de todos os módulos (Hipólito et al., 2017). Os modelos representam tanto a oferta de serviços quanto a localização e as atividades de pessoas que se beneficiam de serviços.

Os modelos do InVEST são espacialmente explícitos: usam mapas como fontes de informação e produzem mapas como resultados, e retornam os resultados em termos biofísicos ou em termos econômicos (Sharp et al., 2020). Todos os módulos do software InVEST 3.12.0, e também as ferramentas adicionais, com orientações gerais para seu uso, estão disponíveis no site do Natural Capital Project (https://naturalcapitalproject.stanford.edu/software/invest) e podem ser acessados e baixados gratuitamente.

No projeto "Construção do conhecimento e sistematização de experiências sobre valoração e pagamento por serviços ecossistêmicos e ambientais no contexto da agricultura familiar amazônica (ASEAM)" estão sendo utilizados os seguintes modelos do InVEST: *Carbon; Sediment Delivery Ratio, Hydropower Production* e *Nutrient Delivery Ratio Model*. Para a valoração econômica da água e do solo (erosão), está sendo utilizado o método de reposição preconizado pela Economia Ambiental. A valoração do carbono está sendo feita via "mercado de carbono", através de análise de preços da tonelada equivalente de CO_2. As áreas de estudo do projeto Aseam compreendem a Bacia do Ribeirão Taxidermista, município de Alta Floresta (MT); Bacia do Rio Piririm, municípios de Macapá, Ferreira Gomes, Itaubal e Cotias (AP); Bacia do Rio Ituxi, municípios de Acrelândia, Senador Guiomard e Plácido de Castro (AC); bacias dos Igarapés Preto e Abacaxi, município de Machadinho d'Oeste (RO); Bacia do Rio Douradão, município de Apuí (AM); Bacia do Igarapé Açu, municípios de Capanema e Peixe-Boi (PA); Bacia do Rio Água Preta, municípios de Governador Newton Bello e Zé Doca (MA); projeto de Assentamento Agroextrativista Bacuri I, município de Cajari (MA).

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Article

Land Use, Climate, and Socioeconomic Factors Determine the Variation in Hydrologic-Related Ecosystem Services in the Ecological Conservation Zone, Beijing, China

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Abstract: The hydrologic-related ecosystem services of upstream ecological conservation zones have an important role in regulating the water scarcity and intense water conflicts of downstream regions. The joint effect of socioeconomic, land use, and climate factors on hydrologic-related ecosystem services is rarely analyzed; hence, its spatial heterogeneity and drivers remain unclear. We used the InVEST model and multivariate analysis to assess the interactions of land use, climate, and socioeconomic factors on hydrologic-related ecosystem services in the Beijing Ecological Conservation Development Zone (BECD) from 2000 to 2018. Our results show that land use shifts were mainly manifested by the conversion of cropland to forestland, grass land, and urban land, with conversion areas of 432 km^2, 84.86 km^2, and 162.57 km^2, respectively. Water yield and water purification services exhibited significant temporal and spatial heterogeneity within the BECD. We also found that land use had the greatest impact on hydrologic-related ecosystem services, followed by climate and socioeconomic factors, with contributions of 44.29%, 7.09%, and 4.16%, respectively. Additionally, the contribution of the joint effect of land use and climate accounted for 13%. This study not only describes the variation in hydrologic-related ecosystem services within the BECD, but also offers a theoretical basis for policymakers and stakeholders to formulate land use policies.

Keywords: hydrologic-related ecosystem services; land use; water yield; water purification; climate change; socioeconomic

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1. Introduction

Ecosystem services can be defined as the direct and indirect contributions of ecosystems to humankind and are a bridge between natural ecosystems and the sustainable development of human societies [1–3]; hence, they have been a hot research topic in recent years [4,5]. Ecosystem services reflect the supply capacity of ecosystems to meet human needs based on the ecological structure and processes [5] and provide a broad range of basic life-support processes, such as water purification, water supply, and ecosystem goods (crops and timber), which play a vital role in human existence and development [3,6,7]. Due to the importance of water resources and the water cycle in ecosystems and human sustainable development, hydrologic-related ecosystem services have been the focus of attention in this field, especially in areas with acute water conflicts [8,9]. In hydrologic-related ecosystems, water provision and water purification are of interest because they can support the delivery of crucial ecosystem services [8], such as water purification, which can restore eutrophic waters and improve drinking water and species diversity [10].

forests

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Article

Quantifying Ecosystem Service Trade-Offs to Inform Spatial Identification of Forest Restoration

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Abstract: Specific forest restoration aims to maximum ecosystem services (ESs); however, the complex trade-offs among ecosystem services pose considerable challenges for fulfilling such goals. Based on forest restoration on Hainan Island, China, we integrated spatially explicit models of ecosystem services and spatial prioritization techniques based on the efficiency frontier between habitat quality and plantation revenue to analyze the impacts of decision-makers' preferences on optimal configurations of forest restoration. We then investigated the effects of different optimal restoration schemes on water purification, soil retention, carbon sequestration, and coastal hazard mitigation. Based on our results, plantation revenue and habitat quality exhibited an obvious trade-off during the process of restoration. Forest restoration patterns also varied with the degree of preference for plantation yield or habitat quality, indicating that understanding ecosystem service tradeoffs can support the optimal selection of forest restoration schemes under different preferences. However, when the values of multiple ecosystem services associated with forest restoration were considered (e.g., water purification, soil retention, carbon sequestration, and coastal hazard mitigation), the optimal solution choice varied. Our results suggest the application of the efficiency frontier can deepen quantitative understanding of ecosystem service trade-offs, and the addition of multi-benefit evaluation based on optimal solutions can provide a more detailed and broader picture of forest restoration plans. Integrated efficiency frontier assessment with the valuation of ecosystem services associated with forest restoration provides a quantitative approach for optimal forest restoration, which can be applied in broad forest restoration programs.

Keywords: ecosystem services; trade-offs; efficiency frontier; spatial land-use planning

1. Introduction

To fulfill the growing needs of food, timber, fiber, and other goods, many natural habitats have been rapidly converted to human-dominated landscapes. With the rise in land-use intensification, trade-offs among ecosystem services (ESs) can intensify simultaneously [1]. Ecological restoration, as a major strategy to improve ecosystem services and reverse biodiversity losses, has been used worldwide [2]. For example, under the Bonn Challenge, a global effort to restore 350 million hectares of deforested and degraded land to national forest by 2030, over 30 countries have made commitments to undertake restoration activity [3]. However, the great challenges for restoration are the trade-offs between available land resources and increasing demands for better services and the trade-offs among ecosystem services [4,5]. Specifically, for the low-income regions or countries, balancing provision services that might strongly link to local poor livelihoods, and biodiversity and regulating services, is vital for a sustainable development [6]. How to utilize limited restoration resources (e.g., land,

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Review

Models for Assessing Urban Ecosystem Services: Status and Outlooks

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Abstract: Urban ecosystem services provide many benefits for human beings. Given the dramatic increase of urbanization, maintaining sustainability of cities relies heavily on ecosystem services, and it is crucial for quantifying, managing, and optimizing urban ecosystem services to promote social and ecological sustainable development. This study presents the review of models for assessing urban ecosystem services through gathering the pertinent literatures which were published recent years. The main types of approaches for assessing urban ecosystem services were summarized, and the model simulation approach was detailed. From modelling techniques to the existing models, it was found that a process-based model is, relatively, a better way to detect the mechanism of urban ecological processes and simulate the future dynamic changes of urban ecosystem services. Three key limitations of existing products and frameworks were identified: (1) lacking understanding of multiple urban ecosystem services interactions, (2) ignoring accounting the socioeconomic factors into dynamics of urban ecosystem, and (3) lacking considerations of feedback effects between social system and urban ecosystem. The study concludes with outlooks that a comprehensive social-ecosystem model based on the social-ecological framework is helpful to reveal the relationships and interactions among various urban ecosystem services, and can better assess how human-induced urban growth affects ecosystem services, and better describe the feedback effect between the social environment and urban ecosystem services, as well as dynamically predict the changes of urban ecosystem services under different scenarios in future long time series.

Keywords: urban ecosystem service; assessing; modelling techniques; social-ecosystem

Citation: Ouyang, X.; Luo, X. Models for Assessing Urban Ecosystem Services: Status and Outlooks. *Sustainability* **2022**, *14*, 4725. https://doi.org/10.3390/su14084725

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1. Introduction

Ecosystem provides many benefits for human-beings, and people still rely on ecosystem services even in modern society, with increasingly developed science and technology. These various services provided by the ecosystems were conceived in the 1970s [1,2], and the term "ecosystem services" did not appear formally until 1981 [3]. Early definitions of ecosystem services emphasized that benefits are directly or indirectly provided to humans by natural ecosystem processes and functions [4,5]. In the developing process of the definitions of ecosystem services, the core of definition is always concentrated on the relationship between ecosystem and human wellbeing. As the definition had been developing continuously, both the natural components [6] and ecological phenomenon [7] could be defined as the source of services; meanwhile, all benefits for humans [8] or all contribution to human wellbeing [9] were also considered as ecosystem services.

The urban ecosystem is a complex human-dominated system, involving with many factors and interactions in several fields, such as natural environment, social economy, and culture. Given its complexity and, particularity, the previous definitions of ecosystem, services cannot be well adapted to the studies of urban ecosystem. However, there are relatively few definitions of urban ecosystem services (UES) at present. Bolund and

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Article

Analysis of Ecosystem Service Trade-Offs and Synergies in Ulansuhai Basin

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Abstract: As an important grain production base and ecological barrier zone in China, Ulansuhai Basin provides a variety of important ecosystem services and ensures human well-being, and it is essential to maintain the sustainable development of the regional ecology–economy–society. Therefore, in order to explore the trade-offs and synergies between ecosystem services in Ulansuhai Basin, we first evaluated the spatio-temporal characteristics of five ecosystem services in 2000, 2005, 2010, 2015, and 2018 based on the InVEST model, including soil conservation, carbon storage, water production, water purification, and food supply. We then further analyzed the trade-offs and synergies of ecosystem services in Ulansuhai Basin and in different functional areas through using the Spearman correlation coefficient. The results show that different ecosystem services had obvious regional differences due to different land-use types in Ulansuhai Basin. Soil conservation, carbon storage, and water production were higher in the eastern region and lower in the central and western regions, while water purification and food supply were higher in the central region and lower in the eastern and western regions. Ecosystem services showed an overall increasing trend from 2000 to 2018. Moreover, trade-off was the dominant relationship between different ecosystem services, and trade-offs and synergies showed strengthening trends to a certain extent. The trade-offs and synergies of ecosystem services in different functional areas were obviously different. Our study aimed to clarify the trade-offs and synergies between ecosystem services and to propose ecological protection and management countermeasures and suggestions, which can provide decision-making reference for regional ecological protection and management.

Keywords: ecosystem services; InVEST model; trade-offs; synergies; basin management

Citation: Wang, L.; Yu, E.; Li, S.; Fu, X.; Wu, G. Analysis of Ecosystem Service Trade-Offs and Synergies in Ulansuhai Basin. *Sustainability* **2021**, *13*, 9839. https://doi.org/10.3390/su13179839

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1. Introduction

Ecosystem services (ESs) are the natural environmental conditions and effects formed and maintained by ecosystems and ecological processes, as well as the benefits directly or indirectly derived from the ecosystem, upon which humans and other organisms depend [1]. As the link and bridge between ecosystems and social systems [2,3], ecosystem services are closely related to human wellbeing [4,5]. However, with the intensification of global climate change and increasing human activities, regional ecosystem service functions have undergone significant changes, affecting the sustainable development of regional ecology, economy, and society [6,7]. Especially, when human disturbance exceeds the tolerance of the ecosystem, the stability of the ecosystem structure can be destroyed, leading to ecological and environmental problems such as habitat fragmentation and ecosystem function degradation [8]. Therefore, the study of ecosystem service evaluation and its trade-offs and synergies have become the focus of many scholars.

However, related research has mostly focused on the spatial interaction of ecosystem services and their manifestations [9,10]. The types of ecosystem services are diverse, and all types of ecosystem services are interrelated, which often reflects in their synergistic

sustainability

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Article

Ecosystem Services Supply–Demand Matching and Its Driving Factors: A Case Study of the Shanxi Section of the Yellow River Basin, China

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Abstract: Understanding the supply–demand relationships and driving mechanisms of ecosystem services (ES) provides a theoretical foundation for sustainable ecosystem management. This study utilized Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) models and geographical detectors to quantify the spatial–temporal patterns of the supply, demand, and supply–demand ratio of ESs such as water yield, soil conservation, and carbon sequestration, along with their driving factors, in the Shanxi section of the Yellow River Basin. The results show that: (1) From the year 2000 to 2020, although the supply and demand of water yield, soil conservation, and carbon sequestration fluctuated, they generally increased during this period of time. In comparison to ecosystem services from the year 2000 to 2020, the supply of water yield exceeded the demand in 2020. The supply, demand, and supply–demand ratio of ESs exhibited notable spatial heterogeneity. (2) The most notable factors influencing the supply–demand ratio of water yield varied between 2000 and 2020. In 2000, construction land was the most important factor, while in 2020, cropland had the greatest impact. However, the primary factors affecting the supply–demand ratio of soil conservation and carbon sequestration remained the same in 2000 and 2020. Forestland was the primary factor in 2000, while construction land was the primary factor in 2020. (3) Considering interaction factors, the interaction factors between construction land and precipitation had the greatest impact on the supply–demand ratio of water yield in 2000, while the interaction between forestland and cropland had the greatest impact in 2020. The interaction between cropland and shrubland had the greatest impact on the supply–demand ratio of soil conservation in 2000, whereas the interaction factors between construction land and forestland had the greatest impact in 2020. The interaction between construction land and shrubland had the greatest impact on the supply–demand ratio of carbon sequestration in 2000, while the interaction between construction land and cropland had the greatest impact in 2020. Overall, the interaction between construction land and various land-use factors had the strongest explanation for the supply–demand ratio of ecosystem services. This study can serve as a reference for the comprehensive development and utilization of the Shanxi section of the Yellow River Basin.

Keywords: ecosystem services; supply and demand patterns; driving factors; Shanxi section of the Yellow River Basin

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Citation: Xu, M.; Feng, Q.; Zhang, S.; Lv, M.; Duan, B. Ecosystem Services Supply–Demand Matching and Its Driving Factors: A Case Study of the Shanxi Section of the Yellow River Basin, China. *Sustainability* **2023**, *15*, 11016. https://doi.org/10.3390/su151411016

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1. Introduction

Ecosystem services refer to the various benefits, including provisioning, regulating, cultural, and supporting services, that humans directly or indirectly obtain from ecosystems [1–4]. Ecosystem service supply refers to the ability of an ecosystem to provide particular goods and services under specific spatial and temporal conditions. Ecosystem service demand refers to the total amount of ecological goods and services that humans

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Xu, M., Feng, Q., Zhang, S. et al. (2023). Ecosystem Services Supply–Demand Matching and Its Driving Factors: A Case Study of the Shanxi Section of the Yellow River Basin, China. Sustainability. [Online]. 15 (14). p.p. 11016. http://dx.doi.org/10.3390/su151411016

F.4. ROSETTA MODEL

CG9. F4

1. Descripción

Rosetta Model es un programa para estimar las propiedades hidráulicas no saturadas a partir de datos de suelo como son la textura o la densidad aparente. Los modelos de este tipo se denominan funciones de pedotransferencia, ya que convierten los datos básicos del suelo en propiedades hidráulicas interpretables. Este programa ofrece hasta 5 de estas funciones dependiendo del conjunto de datos de entrada que van a permitir predecir las propiedades hidráulicas con conjuntos de datos de entrada. Los modelos siguen la siguiente secuencia jerárquica de datos de entrada:

- Clase textural del suelo.
- Porcentajes de arena, limo y arcilla.
- Porcentajes de arena, limo y arcilla y densidad aparente.
- Porcentajes de arena, limo y arcilla y densidad aparente y un punto de retención de agua a 330 cm.
- Porcentajes de arena, limo y arcilla y densidad aparente y puntos de retención de agua a 330 y 15.000 cm.

Todos los parámetros hidráulicos estimados están acompañados por estimaciones de incertidumbre que permiten hacer una evaluación del grado de confianza de las predicciones obtenidas.

Este software es del año 1999, actualizado en 2017 a la versión 3 y está desarrollado por el laboratorio de salinidad del Servicio de Investigación Agrícola del Departamento de Agricultura de Estados Unidos (USDA-ARS).

Las principales investigaciones en las que se ha usado Rosseta Model recientemente son (Borek et al., T.,2021; Domóngues-Niño et al., 2020; Gupta et al., 2022; Guram y Bashir, 2023).

2. Características técnicas

Programa	Rosetta model		
Versión	3.	Año	2017
Tipología	Gestión de recursos naturales		
Capacidades del programa	Rosetta es un programa para estimar las propiedades hidráulicas no saturadas a partir de datos específicos del suelo como la textura o su densidad aparente. Estos modelos producen funciones de pedotransferencia porque convierten datos básicos del suelo en propiedades hidráulicas. Este programa puede usarse para estimar las siguientes propiedades: parámetros de retención del agua según van Genuchen, conductividad hidráulica saturada y parámetros de conductividad hidráulica no saturados según van Genuchen y Mualem.		
Sistema operativo	Linux (64 bits)		
	Windows (64 bits)		
	macOS X (64 bits)		
Tipo de sistema (arquitectura)	64 bits	Tipo de licencia	Código Abierto licenciado bajo GNU/GPL (General Public License)
Desarrollador	U. S. Salinity Laboratory (United States Departament of Agriculture, USDA), Zhang, Y., Schaap, M.G.,		
Web	https://soil-modeling.org/resources-links/model-portal/rosetta		

3. Ejemplos de trabajos científicos

land

MDPI

Article

Use of Pedotransfer Functions in the Rosetta Model to Determine Saturated Hydraulic Conductivity (Ks) of Arable Soils: A Case Study

Łukasz Borek *, Andrzej Bogdał and Tomasz Kowalik

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Abstract: A key parameter for the design of soil drainage and irrigation facilities and for the modelling of surface runoff and erosion phenomena in land-formed areas is the saturated hydraulic conductivity (Ks). There are many methods for determining its value. In situ and laboratory measurements are commonly regarded as the most accurate and direct methods; however, they are costly and time-consuming. Alternatives can be found in the increasingly popular models of pedotransfer functions (PTFs), which can be used for rapid determination of soil hydrophysical parameters. This study presents an analysis of the Ks values obtained from in situ measurements conducted using a double-ring infiltrometer (DRI). The measurements were conducted using a laboratory permeability meter (LPM) and were estimated using five PTFs in the Rosetta program, based on easily accessible input data, i.e., the soil type, content of various grain sizes in %, density, and water content at 2.5 and 4.2 pF, respectively. The degrees of matching between the results from the PTF models and the values obtained from the in situ and laboratory measurements were investigated based on the root-mean-square deviation (*RMSD*), Nash–Sutcliffe efficiency (*NSE*), and determination coefficient (R2). The statistical relationships between the tested variables tested were confirmed using Spearman's rank correlation coefficient (rho). Data analysis showed that in situ measurements of Ks were only significantly correlated with the laboratory tests conducted on intact samples; the values obtained in situ were much higher. The high sensitivity of Ks to biotic and abiotic factors, especially in the upper soil horizons, did not allow for a satisfactory match between the values from the in situ measurements and those obtained from the PTFs. In contrast, the laboratory measurements, showed a significant correlation with the Ks values, as estimated by the models PTF-2 to PTF-5; the best match was found for PTF-2.

Keywords: soil; saturated hydraulic conductivity; pedotransfer function; Rosetta program; irrigation; climate change

Citation: Borek, Ł.; Bogdał, A.; Kowalik, T. Use of Pedotransfer Functions in the Rosetta Model to Determine Saturated Hydraulic Conductivity (Ks) of Arable Soils: A Case Study. *Land* **2021**, *10*, 959. https://doi.org/10.3390/land10090959

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1. Introduction

Water permeability is a key property of soils, especially with regard to the design of soil irrigation and drainage facilities, modelling of surface runoff and erosion phenomena in land-formed areas, and environmental processes occurring in porous media [1–3]. The study of soil physics, and in particular the determination of the filtration coefficient (Ks) based on direct methods, is a very interesting issue; nevertheless, it is both labour-intensive and costly [4–9].

Climate change in a region or environment entail changes in the method of soil cultivation and plant production. Changes in the interactions between agriculture (i.e., soil compaction) and natural environment (i.e., weather, soil conditions) are a key feature of the transitions which scientists are trying to explain. Therefore, learning the landscape is an important tool in the proper management of water resources in rural areas. Agricultural

water

MDPI

Article

Parameterization of Soil Hydraulic Parameters for HYDRUS-3D Simulation of Soil Water Dynamics in a Drip-Irrigated Orchard

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Abstract: Although surface drip irrigation allows an efficient use of water in agriculture, the heterogeneous distribution of soil water complicates its optimal usage. Mathematical models can be used to simulate the dynamics of water in the soil below a dripper and promote: a better understanding, and optimization, of the design of drip irrigation systems, their improved management and their monitoring with soil moisture sensors. The aim of this paper was to find the most appropriate configuration of HYDRUS-3D for simulating the soil water dynamics in a drip-irrigated orchard. Special emphasis was placed on the source of the soil hydraulic parameters. Simulations parameterized using the Rosetta approach were therefore compared with others parameterized using that of HYPROP + WP4C. The simulations were validated on a seasonal scale, against measurements made using a neutron probe, and on the time course of several days, against tensiometers. The results showed that the best agreement with soil moisture measurements was achieved with simulations parameterized from HYPROP + WP4C. It further improved when the shape parameter n was empirically calibrated from a subset of neutron probe measurements. The fit of the simulations with measurements was best at positions near the dripper and worsened at positions outside its wetting pattern and at depths of 80 cm or more.

Keywords: HYDRUS-3D; simulation; soil water content; tensiometer; neutron probe; Rosetta; HYPROP; WP4C; soil wetting patterns

1. Introduction

Agriculture is one of the activities that consumes most fresh water in the world—approximately 70% [1]. As population increases, so does the need for food and, as a consequence, the demand for water [2,3]. It is therefore necessary to develop methods to improve the efficiently of water management [4]. Drip irrigation is one of the most effective systems, since it gives irrigators a great deal of control over the amount of water that they use and helps to optimize parameters such as: the frequency and duration of irrigation, the discharge rate of the emitter, and the positioning of the emitters. This, in turn, helps to reduce water loss due to evaporation, percolation and runoff [5–7].

remote sensing

MDPI

Article

Global Mapping of Soil Water Characteristics Parameters—Fusing Curated Data with Machine Learning and Environmental Covariates

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Abstract: Hydrological and climatic modeling of near-surface water and energy fluxes is critically dependent on the availability of soil hydraulic parameters. Key among these parameters is the soil water characteristic curve (SWCC), a function relating soil water content (θ) to matric potential (ψ). The direct measurement of SWCC is laborious, hence, reported values of SWCC are spatially sparse and usually have only a small number of data pairs (θ, ψ) per sample. Pedotransfer function (PTF) models have been used to correlate SWCC with basic soil properties, but evidence suggests that SWCC is also shaped by vegetation-promoted soil structure and climate-modified clay minerals. To capture these effects in their spatial context, a machine learning framework (denoted as Covariate-based GeoTransfer Functions, CoGTFs) was trained using (a) a novel and comprehensive global dataset of SWCC parameters and (b) global maps of environmental covariates and soil properties at 1 km spatial resolution. Two CoGTF models were developed: one model (CoGTF-1) was based on predicted soil covariates because measured soil data are not generally available, and the other (CoGTF-2) used measured soil properties to model SWCC parameters. The spatial cross-validation of CoGTF-1 resulted, for the predicted van Genuchten SWCC parameters, in concordance correlation coefficients (CCC) of 0.321–0.565. To validate the resulting global maps of SWCC parameters and to compare the CoGTF framework to two pedotransfer functions from the literature, the predicted water contents at 0.1 m, 3.3 m, and 150 m matric potential were evaluated. The accuracy metrics for CoGTF were considerably better than PTF-based maps.

Keywords: soil hydraulic properties; remote sensing; CoGTF; van Genuchten parameters

Citation: Gupta, S.; Papritz, A.; Lehmann, P.; Hengl, T.; Bonetti, S.; Or, D. Global Mapping of Soil Water Characteristics Parameters—Fusing Curated Data with Machine Learning and Environmental Covariates. *Remote Sens.* **2022**, *14*, 1947. https://doi.org/10.3390/rs14081947

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1. Introduction

The quantification of hydrological processes in the soil unsaturated zone (infiltration, runoff, drainage, evaporation, and water storage) is critically dependent on the quality of parameters of the soil water characteristics curve (SWCC) describing the relationship between soil water content (θ) and matric potential (ψ) [1–3]. Computing climatic predictions by contemporary land surface models (LSMs) requires highly resolved maps of SWCC parameters for the terrestrial surface of the Earth.

This rapidly expanding need for spatially exhaustive and highly resolved maps of SWCC parameters has prompted the use of readily available soil information such as soil texture to estimate parameters of SWCCs by pedotransfer functions (PTFs) [4,5]. PTFs

hydrology

MDPI

Article

Examination of Measured to Predicted Hydraulic Properties for Low Impact Development Substrates

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* Correspondence: rbashir@yorku.ca

Abstract: To counter the impacts of climate change and urbanization, engineers have developed ingenious solutions to reduce flooding and capture stormwater contaminants through the use of Low Impact Developments (LIDs). The soil is generally considered to be completely saturated when designing for the LIDs. However, this may not always be an accurate or realistic approach, as the soil could be variably unsaturated leading to inaccurate designs. To analyse the flow under variably unsaturated conditions, Richards' equation can be used. To solve the Richards' equation, two nonlinear hydraulic properties, namely soil water characteristic curve (SWCC) and the unsaturated hydraulic conductivity function are required. Laboratory and field measurements of unsaturated hydraulic properties are cumbersome, expensive and time- consuming. Pedotransfer functions (PTFs) estimate soil hydraulic properties using routinely measured soil properties. This paper presents a comparison between the direct measurement obtained through experimental procedures and the use of PTFs to estimate soil hydraulic properties for two green roof and three bioretention soil medias. Comparison between the measured and estimated soil hydraulic properties was accomplished using two different approaches. Statistical analyses and visual comparisons were used to compare the measured and estimated soil hydraulic properties. Additionally, numerical modelling to predict the water balance at the ground surface was conducted using the measured and estimated soil hydraulic properties. In some instances, the use of predicted hydraulic properties resulted in overestimation of the cumulative net infiltration of as much as 60 % for the green roof substrate, but was considered negligible for the bioretention substrate. Design performance criteria for green roof and bioretention facilities were examined using the measured and estimated soil hydraulic properties under extreme precipitation analysis. Results indicate that there is a high level of uncertainty when using PTFs for LID materials. A percent difference between the measured and predicted properties for the green roof peak time delay under a 2-year storm can be as much as 300%. For the bioretention design criteria of a 25-year storm, the surface runoff was overestimated by 14.7 cm and by 100% for the ponding time percent difference.

Keywords: unsaturated hydraulic properties; low impact development; pedotransfer functions; regression models; physicoempirical models; artificial neural network

Citation: Guram, S.; Bashir, R. Examination of Measured to Predicted Hydraulic Properties for Low Impact Development Substrates. *Hydrology* **2023**, *10*, 105. https://doi.org/10.3390/hydrology10050105

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1. Introduction

The use of pedotransfer functions is seen as a great advantage since measuring hydraulic properties, such as soil water characteristic curves (SWCCs) and hydraulic conductivity, can be time-consuming and costly. Pedotransfer functions (PTFs) estimate soil hydraulic properties using routinely measured soil properties, such as soil texture, bulk density, particle size distribution, or porosity. By compiling and analysing a large quantity of measured soil data, a relationship can be developed thus creating a PTF.

Historically, PTFs were established with natural, native soil in mind rather than engineered substrates such as Low Impact Development (LID) substrates. Studies, such as

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Borek, Ł., Bogdał, A. y Kowalik, T. (2021). Use of Pedotransfer Functions in the Rosetta Model to Determine Saturated Hydraulic Conductivity (Ks) of Arable Soils: A Case Study. Land. [Online]. 10 (9). p.p. 959. http://dx.doi.org/10.3390/land10090959

Domínguez-Niño, J.M., Arbat, G., Raij-Hoffman, I. et al. (2020). Parameterization of Soil Hydraulic Parameters for HYDRUS-3D Simulation of Soil Water Dynamics in a Drip-Irrigated Orchard. Water. [Online]. 12 (7). p.p. 1858. http://dx.doi.org/10.3390/w12071858

Gupta, S., Papritz, A., Lehmann, P. et al. (2022). Global Mapping of Soil Water Characteristics Parameters— Fusing Curated Data with Machine Learning and Environmental Covariates. Remote Sensing. [Online]. 14 (8). p.p. 1947. http://dx.doi.org/10.3390/rs14081947

Guram, S. y Bashir, R. (2023). Examination of Measured to Predicted Hydraulic Properties for Low Impact Development Substrates. Hydrology. [Online]. 10 (5). p.p. 105. http://dx.doi.org/10.3390/hydrology10050105

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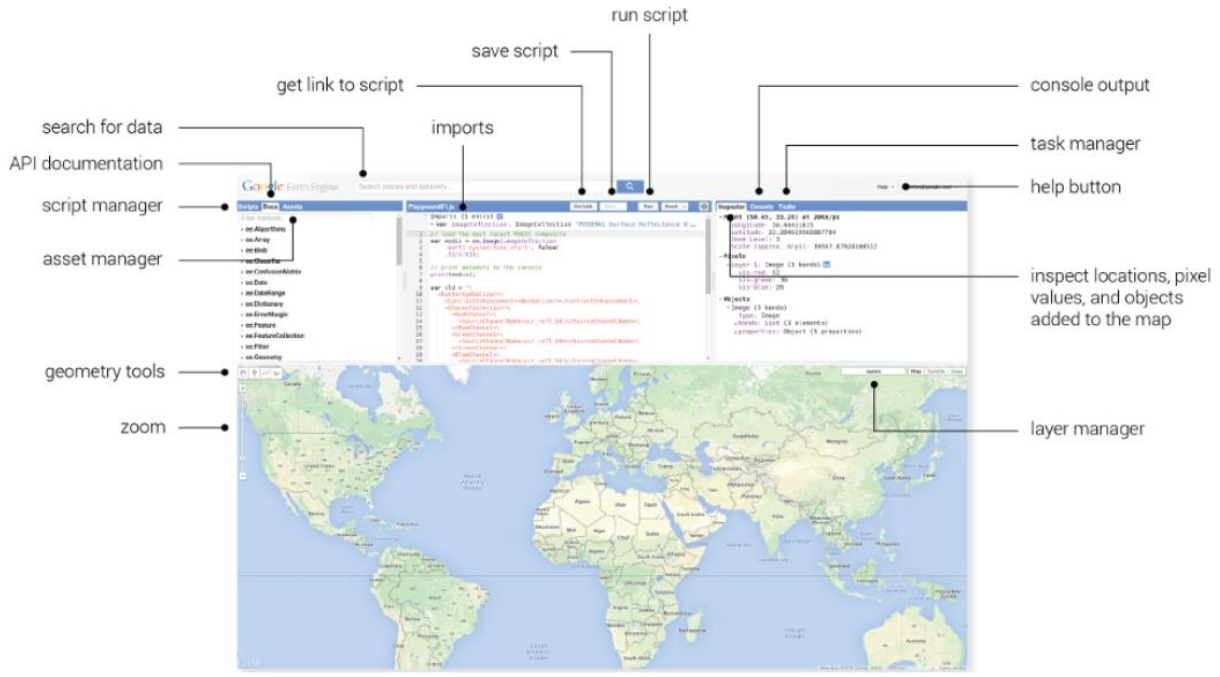
G. SISTEMAS DE DATOS

G1. Plataformas de proceso web

Google Earth Engine

Google Earth Engine es una plataforma informática que permite a los usuarios ejecutar análisis geoespaciales en la infraestructura de Google. Hay varias formas de interactuar con la plataforma. El editor de código es un IDE basado en web para escribir y ejecutar scripts. Explorer es una aplicación web liviana para explorar el catálogo de datos y ejecutar análisis simples. Las bibliotecas cliente proporcionan contenedores de Python y JavaScript para sus API web. https://earthengine.google.com/

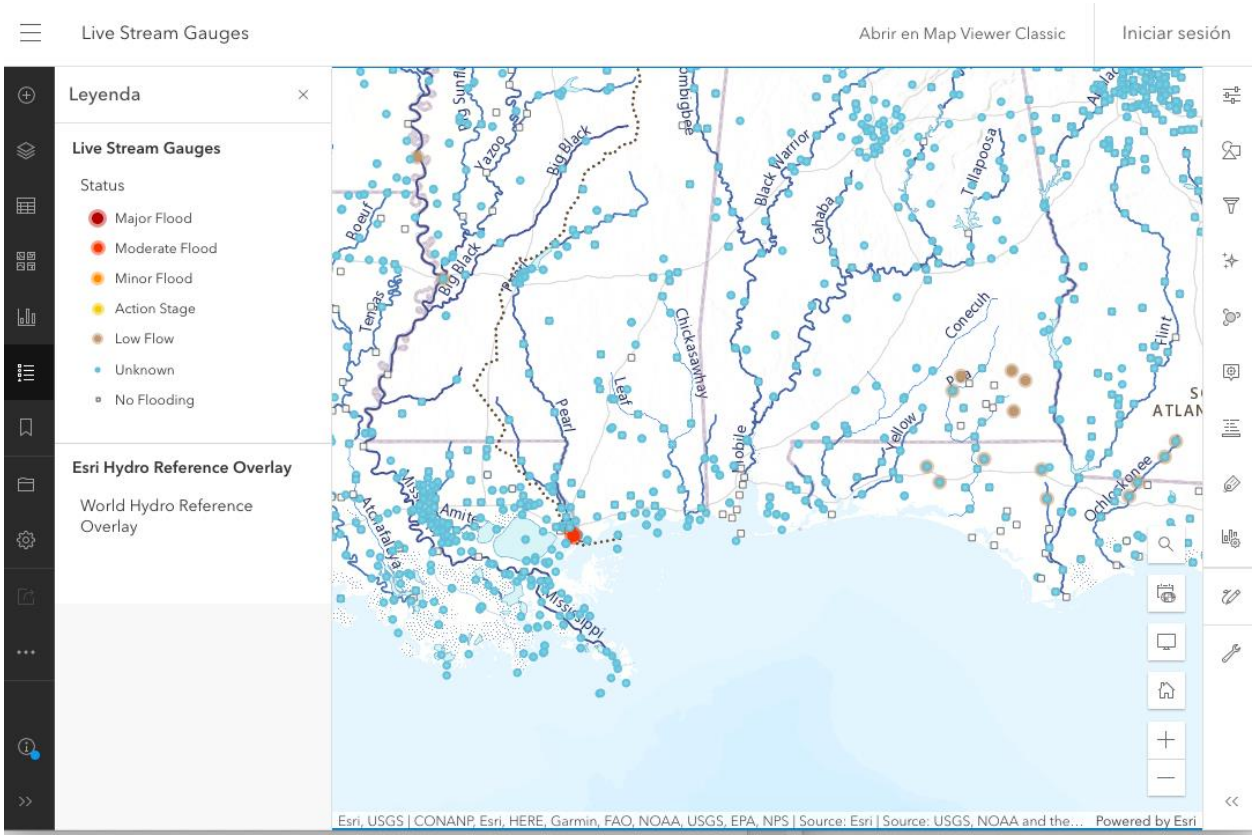


Características principales (https://cloud.google.com/earth-engine#):

- Catálogo de datos públicos de Earth Engine, más de 40 años de imágenes históricas y conjuntos de datos científicos, incluidos datos de satélite como Landsat, Sentinel-2 y MODIS, y datos geofísicos, meteorológicos, climáticos y demográficos.
- Computación, utiliza Google Cloud para procesar petabytes de datos sin configuración ni gestión de servidores.
- APIs de JavaScript, Python y REST con todas las funciones
- Editor de código, IDE basado en la WEB para escribir y ejecutar secuencias de comandos

ArcGIS Living Atlas of the World

Living Atlas of the World de ArcGIS es la principal colección de información geográfica de todo el mundo. Incluye mapas, aplicaciones y capas de datos para ayudarle en su trabajo. https://livingatlas.arcgis.com/es/home/



Características principales:

- Mapas web interactivos para narrar historias y responder preguntas
- Capas, conjuntos lógicos de datos para crear mapas, escenas y análisis.
- Escenas, visualice y analice en un entorno 3D intuitivo e interactivo.

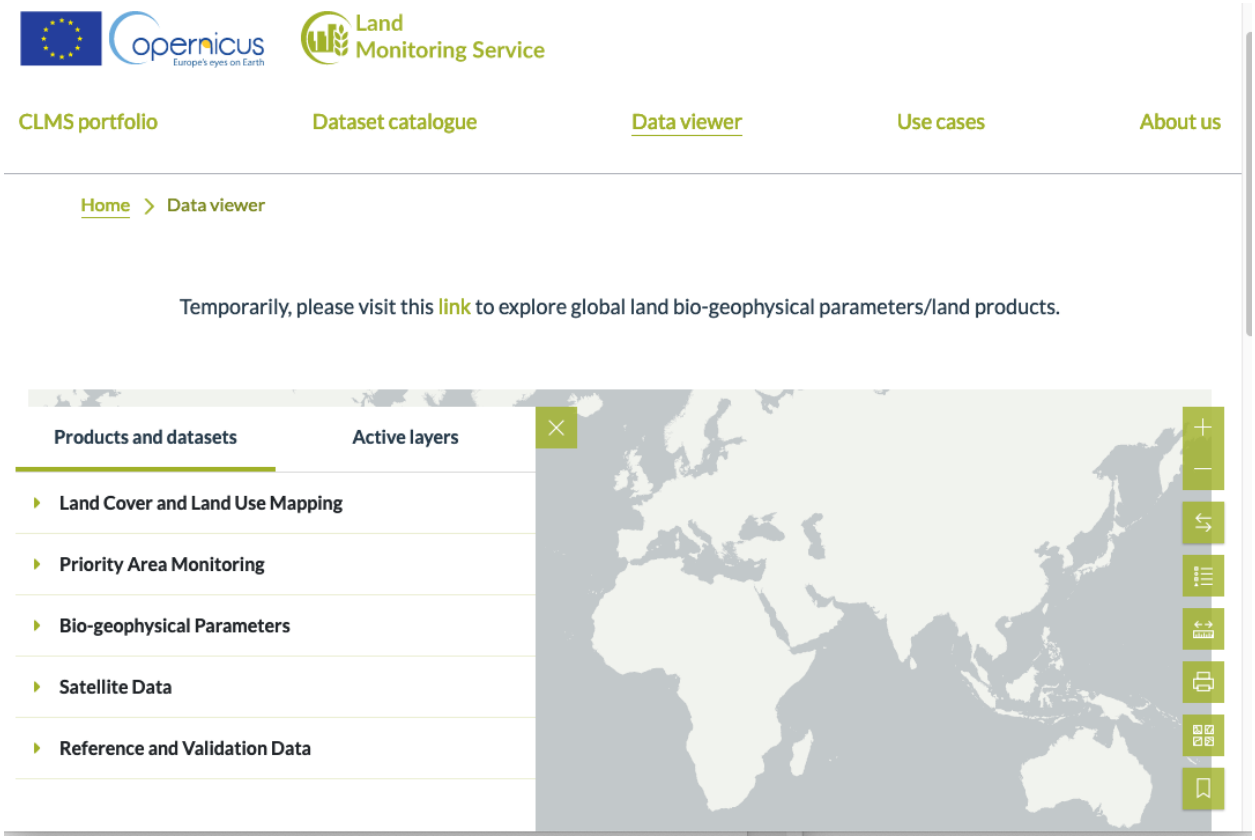
- Aplicaciones, flujos de trabajo y herramientas de uso específico y centrados en los mapas. (Sentinel-2 Land Cover Explorer, Landsat Explorer, Water Balance App, …)
- Herramientas de análisis espacial le permiten cuantificar los patrones y las relaciones de los datos, y mostrar los resultados como mapas, tablas y gráficos.

G2. Repositorios de datos cartográficos

Copernicus Land Monitoring Service

Copernicuso forma parte del Programa Espacial de la Unión Europea. Ofrece servicios de información que se basan en satélites dedicados (las familias Sentinel) y misiones satelitales contribuyentes (satélites comerciales y públicos existentes) y datos in situ (no espaciales).

Copernicus Land Monitoring Service (CLMS) proporciona información geográfica sobre la cobertura del suelo y sus cambios, uso del suelo, movimientos del suelo, estado de la vegetación, ciclo del agua y variables energéticas de la superficie de la Tierra a una amplia gama de usuarios en Europa y en todo el mundo en el campo de las aplicaciones medioambientales terrestres. https://land.copernicus.eu/en



IDEE Infraestructura de Datos Espaciales de España

Una Infraestructura de Datos Espaciales (IDE) es una red en la que diferentes organizaciones publican información geoespacial a través de servicios web normalizados y la catalogan utilizando metadatos. Para ello, asumen una serie de acuerdos y políticas comunes.

El objetivo de la IDEE es integrar en la web los datos, metadatos y servicios geográficos producidos en España, que cumplen las normas, estándares y recomendaciones que permiten su interoperabilidad.

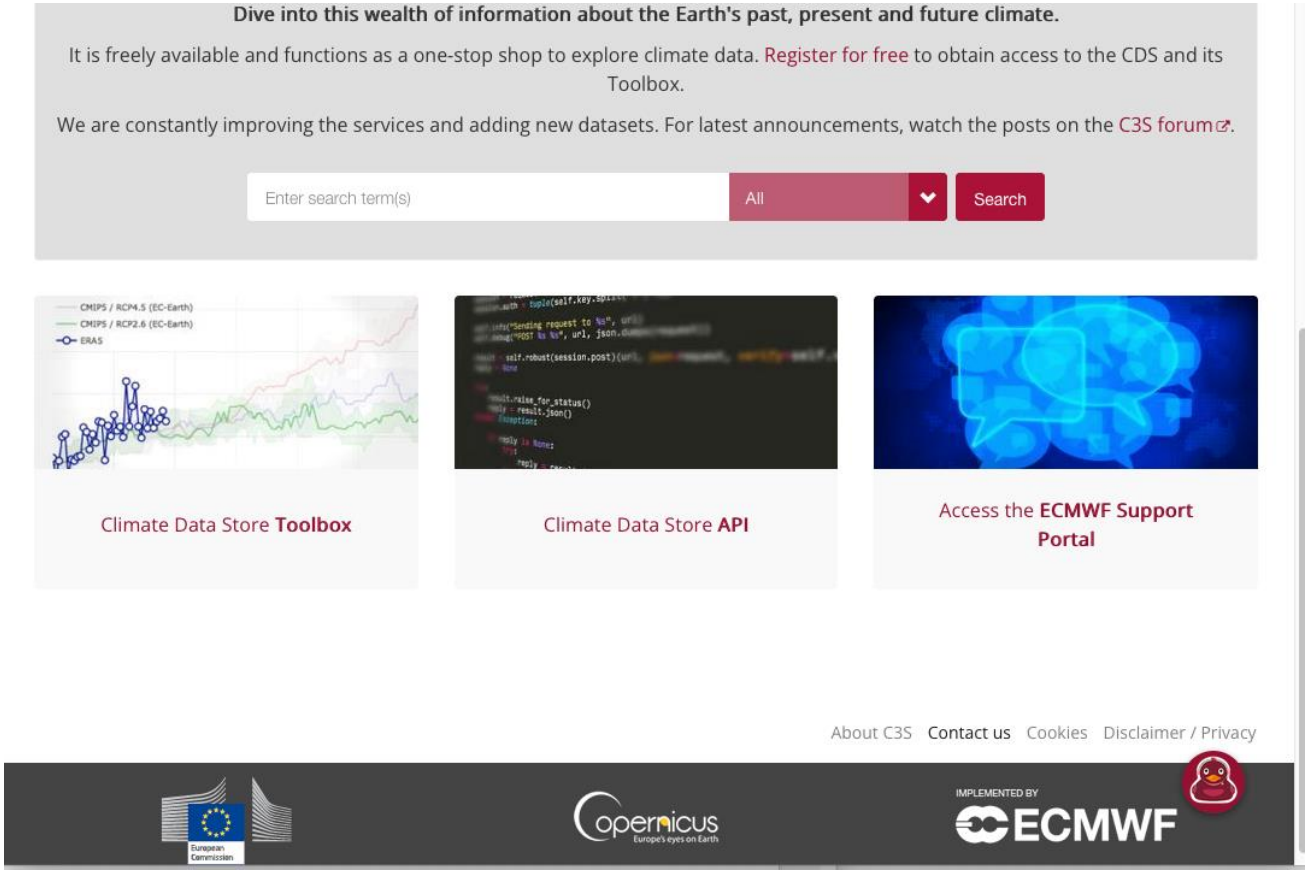
La IDEE integra los nodos IDE de las Administraciones nacional, regional y local, y está preparada para integrar los recursos IDE del sector privado, universidades, ONG, otras organizaciones y el público en general.

Forma parte de la IDE Europea, definida en la Directiva INSPIRE, transpuesta en España en la mencionada ley LISIGE. Tiene como punto de acceso principal este geoportal, responsabilidad del Instituto Geográfico Nacional.

G3.Repositorios de datos climáticos

Copernicus Climate Change Service

El Servicio de Cambio Climático de Copernicus (C3S) apoya a la sociedad proporcionando información autorizada sobre el clima pasado, presente y futuro en Europa y el resto del mundo (Buontempo et al., 2022, Pasik et al., 2023)). https://climate.copernicus.eu/

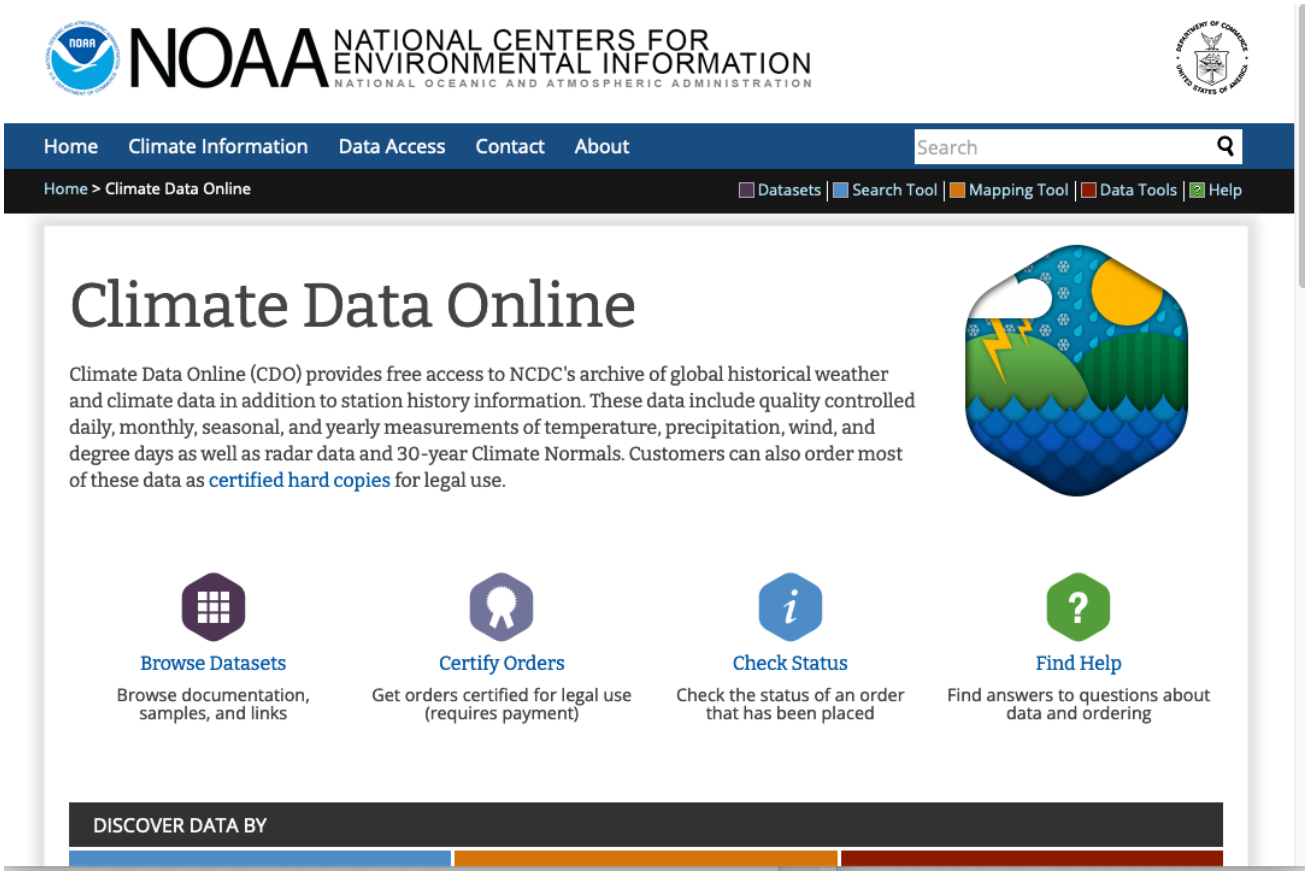


C3S es uno de los seis servicios de información temática proporcionados por el Programa de Observación de la Tierra Copernicus de la Unión Europea. Copernicus es un programa operativo que se basa en las infraestructuras de investigación y el conocimiento existentes disponibles en Europa y otros lugares. C3S se basa en la investigación climática llevada a cabo dentro del Programa Mundial de Investigación del Clima (WCRP) y responde a los requisitos de los usuarios definidos por el Sistema Global de Observación del Clima (GCOS). C3S proporciona un recurso importante para el Marco Mundial para los Servicios Climáticos (MMSC).

NOAA National Center for Environmental Information

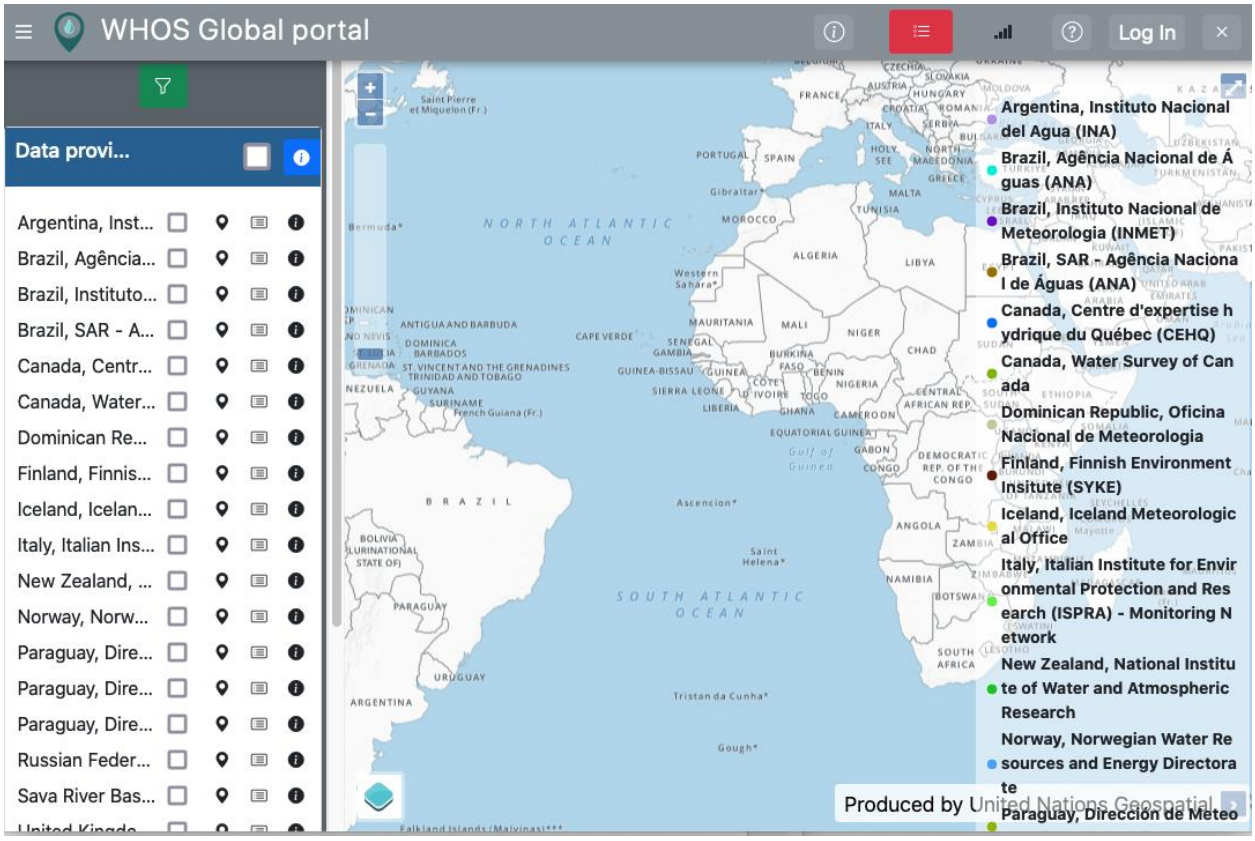
Datos climáticos en línea. Climate Data Online (CDO) proporciona acceso gratuito al archivo del NCDC de datos históricos meteorológicos y climáticos globales, además de información histórica de la estación. Estos datos incluyen mediciones diarias, mensuales, estacionales y anuales de calidad controlada de temperatura, precipitación, viento y grados día, así como datos de radar y normales climáticas de 30 años. Los clientes también pueden solicitar la mayoría de estos datos como copias impresas certificadas para uso legal (Wu et al., 2021).

https://www.ncei.noaa.gov/cdo-web/



WMO Hydrological Observing System (WHOS)

El Sistema de Observación Hidrológica de la Organización Mundial Metereológica (WHOS) facilita el intercambio interoperable de datos hidrológicos. Es una solución multiescalar (local, nacional, regional y global) que utiliza diferentes herramientas y que además proporciona registro de datos y servicios de información hidrológicos, catalogados utilizando los estándares y procedimientos abiertos desarrollados por el Open Geospatial Consortium (OGC), la OMM, W3C, GeoJson y otras organizaciones relevantes (Boldrini et al., 2022; Pecora y Lins, 2020) . https://hydrohub.wmo.int/en/whos



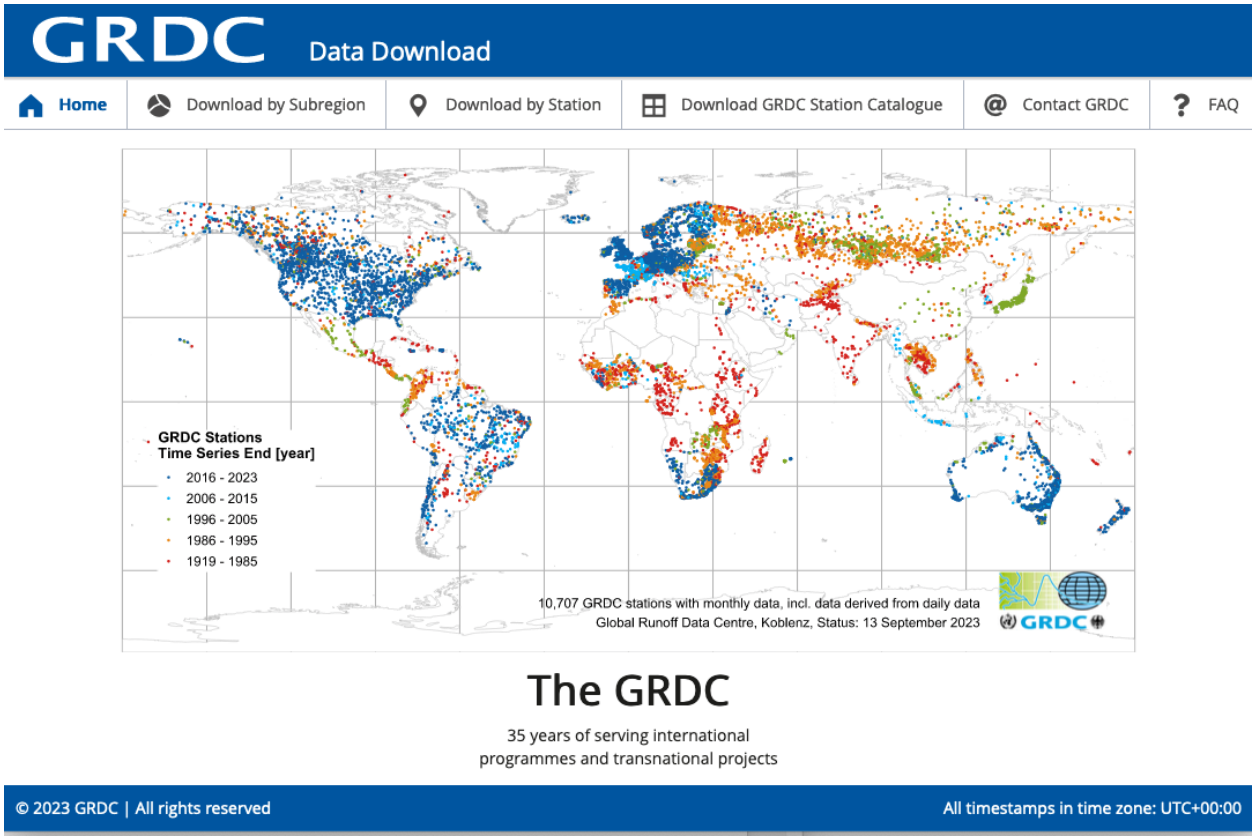
WHOS se está desarrollando e implementando en dos fases:

- 1. proporciona una interfaz cartográfica con enlaces a aquellos SMHN que ponen a disposición en línea sus datos hidrológicos históricos y en tiempo real.
- 2 proporciona un marco orientado a servicios que vincula a los proveedores y usuarios de datos hidrológicos a través de un sistema de información hidrológica de sistemas que permiten el registro, el descubrimiento y el acceso a datos.

G4. Repositorios de datos hidrológicos

GRDC

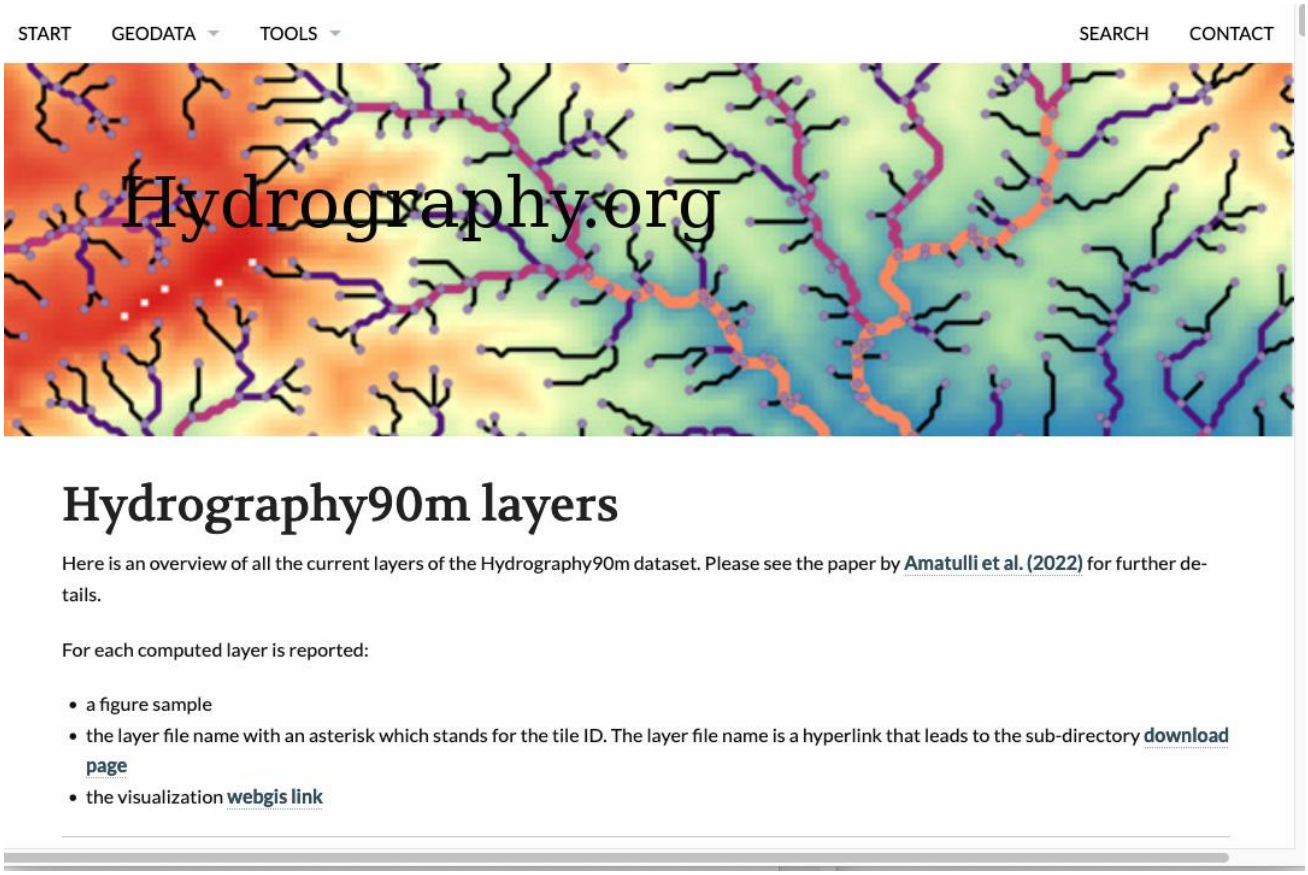
El GRDC (Global Runoff Data Centre) es un archivo internacional de datos de hasta 200 años de antigüedad y fomenta estudios hidrológicos multinacionales y globales a largo plazo. Creado originalmente hace tres décadas, el objetivo del GRDC es ayudar a los científicos a analizar las tendencias climáticas globales y evaluar los impactos y riesgos ambientales. Operando bajo los auspicios de la WMO (World Meteorological Organization), la base de datos de datos de descarga media diaria y mensual "históricos" de calidad controlada crece constantemente y actualmente comprende datos de descarga de ríos de más de 10.000 estaciones de 159 países (Burek et al., 2023; Lv et al., 2018) . https://www.bafg.de/GRDC/EN/Home/homepage_node.html



Hydrography.org

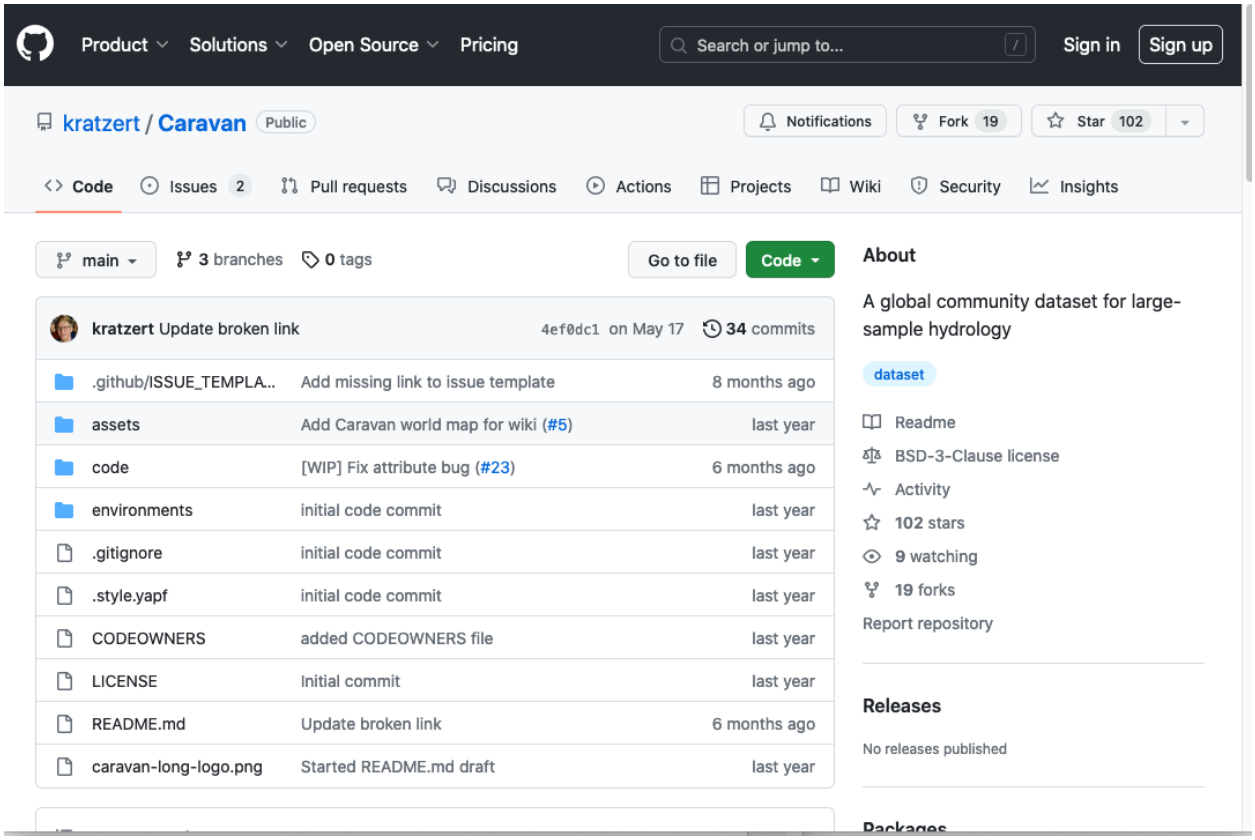
Hydrography.org se centra en difundir capas globales de alta resolución de los canales fluviales de la Tierra junto con un conjunto de información topográfica y topológica. Todos los datos se pueden descargar y proporcionan scripts para facilitar el uso de los datos. Hydrography90m: conjunto de datos de hidrografía global de alta resolución. https://hydrography.org/

Hydrographr proporciona una colección de contenedores R para funciones GDAL y GRASS-GIS, y de esta manera trabajar eficientemente con Hydrography90m y datos de biodiversidad espacial. Las funciones procesan grandes datos rasterizados y vectoriales directamente en el disco en paralelo, de modo que la memoria de R no se sobrecargue, permitiendo crear flujos de trabajo de análisis y procesamiento de datos escalables en R, aunque los datos no se procesen directamente en R. (Amatulli et al., 2022; Schürz et al., 2023). https://github.com/glowabio/hydrographr



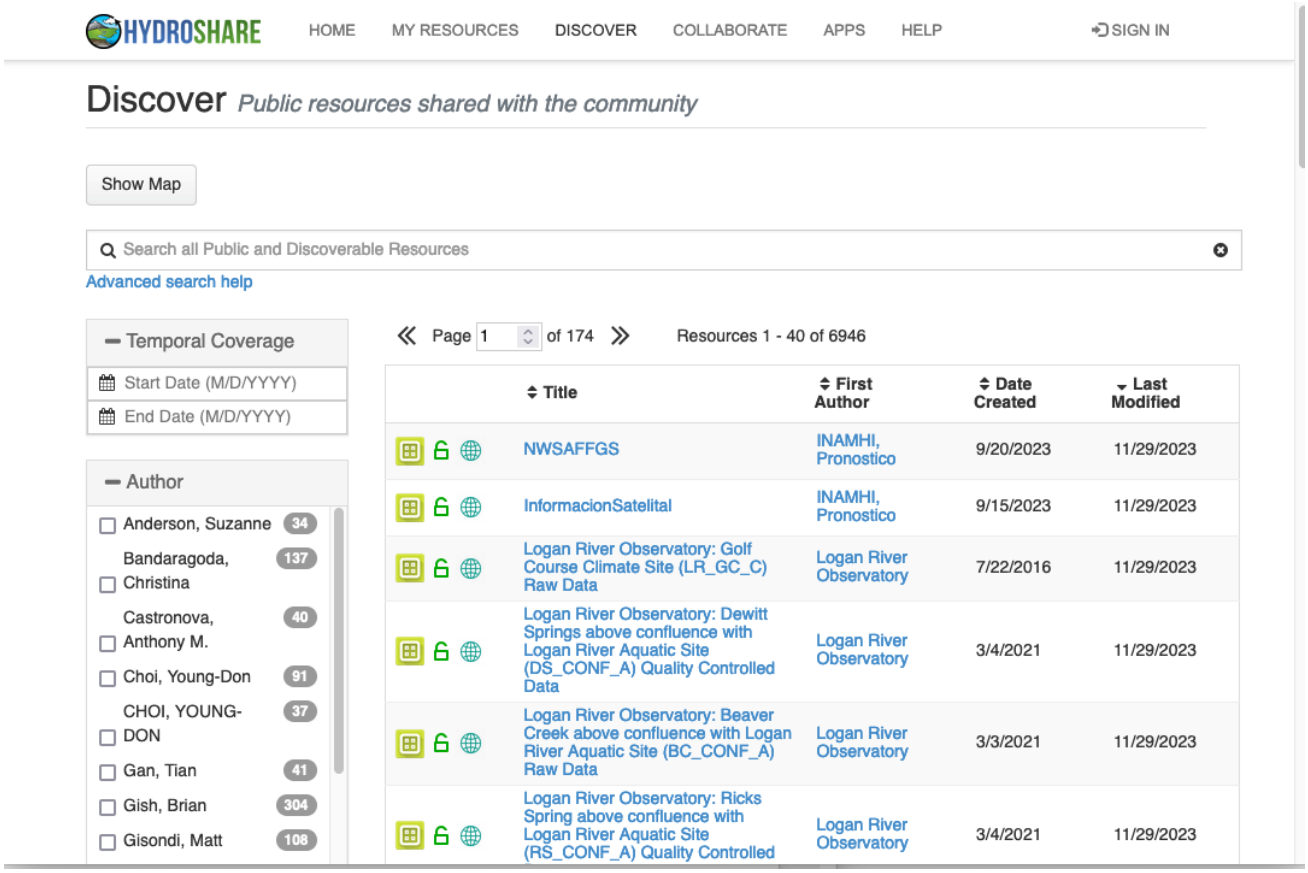
Caravan

Un conjunto de datos comunitario global para hidrología de muestras grandes. Una serie de CAMELS (Catchment Attributes and Meteorology for Large-sample Studies) que estandariza y agrega siete conjuntos de datos hidrológicos de muestras grandes existentes. Caravan incluye datos meteorológicos, datos de caudal y atributos estáticos de cuencas (por ejemplo, geofísicos, sociológicos, climatológicos) para 6830 cuencas. Lo más importante es que Caravan es un conjunto de datos y un software de código abierto que permite a los miembros de la comunidad hidrológica extender el conjunto de datos a nuevas ubicaciones mediante la extracción de datos y atributos de cuenca en la nube (Bouri et al., 2020; Kratzert et al., 2023). https://github.com/kratzert/Caravan



HydroShare

HydroShare es el sistema de información hidrológica basado en web del Consorcio de Universidades para el Avance de la Ciencia Hidrológica, Inc. (CUAHSI) para que los usuarios compartan y publiquen datos y modelos en una variedad de formatos flexibles, y para que esta información esté disponible en un formato citable, compartible y reconocible. Permite a los usuarios colaborar y trabajar en equipos en un entorno colaborativo basado en la web, mejorando así la investigación, la educación y la aplicación del conocimiento hidrológico. Hydroshare incluye herramientas (aplicaciones web) que pueden actuar sobre el contenido de HydroShare, proporcionando a los usuarios una puerta de entrada a la informática y el análisis. (Calyam et al., 2020; Gan et al., 2020) https://www.hydroshare.org/



- Almacena tus datos en línea y compártelos para colaborar y recibir comentarios de otras personas
- Publique permanentemente sus datos y modelos y obtenga un Identificador de objetos digitales (DOI) citable para obtener crédito por sus datos y modelos.
- Accede fácilmente a datos y modelos hidrológicos
- Colabora con otras personas para la investigación hidrológica.

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ÍNDICE DETALLADO

Cuadernos de Geomática 9

La Geomática y sus herramientas para el análisis de los recursos hídricos en 2023

CENTRO PARA EL CONOCIMIENTO DEL PAISAJE

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