出國報告（出國類別：國際研討會）

「2017 年歐洲地球科學聯盟年會」
國際研討會

服務機關：行政院環境保護署土壤及地下水污染整治基金管理會

姓名職稱：陳峻明副執行秘書

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出國期間：106 年 4 月 22 日至 5 月 3 日

報告日期：106 年 7 月 18 日

摘要

參加位於維也納的奧地利維也納會議中心(Austria Center Vienna)，由歐洲地球科學會(European Geosciences Union, EGU)舉辦之「2017 年歐洲地球科學聯盟年會」。

研討會議程主要可分為 31 個學門，總計共逾 4,840 篇口頭發表及 11,300 篇海報論文發表，其中與本署土壤及地下水業務較為相關的學門包括水文科學(Hydrological Sciences)及土壤系統科學(Soil System Sciences)。研討會與會人員包括產官學研各界專家學者、工程師、學生、政府代表、非政府組織代表等總計 14,400 人以上，並來自於 107 個不同國家。

本次會議中，本署發表海報論文一篇，內容係介紹我國地下水水質分類與管理計畫，經由簡要口頭報告及海報展示，與國外學者相互交流，宣揚我國地下水管理先進觀念與作法，獲得國外學者專家肯定。另外，本次會議中也有紐西蘭、歐盟、印度等國代表提出與我國類似的地下水水質分類作法，建議未來可再蒐集世界先進國家管理作法，並尋求機會進行深入交流。

目錄

一、目的

我國自民國 89 年公布實施「土壤及地下水污染整治法」以來，成效卓著，不論從法規制訂、污染調查整治技術到產業發展，各方面均得落實與發展的機會。就整體土壤及地下水環境保護工作而言，不僅領先亞洲各國，也受到歐美等先進國家關注，此點可從本署主辦歷屆國際研討會與環境展，均有各國專家與廠商踴躍參與得到印證。然而我國目前環境保護工作仍面臨巨大挑戰，尤其土壤及地下水污染調查及整治，其技術難度高，所需時間更長，需投入資源更多，因此仍應積極向先進國家學習，參與具水準之大型國際會議，以求他山之石，精進國內之技術能力。另一方面，我國目前外交處境困難，在大型國際會議中介紹我國在環境保護工作成果，實為使國際友人更加認識支持我國的最佳場合與時機。

本次參加位於奧地利維也納會議中心(Austria Center Vienna)，由歐洲地球科學會(European Geosciences Union)舉辦之「2017 年歐洲地球科學聯盟年會」，該年會每年定期於奧地利維也納舉辦，每年皆吸引全球超過萬名專家學者與會，觀摩與發表研究成果，為地球科學界發表研究成果及心得交流討論的重要會議，經此會議可瞭解國際間土壤及地下水資源管理、污染調查、永續利用之新發展趨勢。由此可知，EGU 年會規模盛大，參與人數眾多，正符合前述參與具水準之大型國際會議的要件。

本年度 EGU 年會研討會議程主要可分為 31 個學門，總計共逾 4,840 篇口頭發表及 11,300 篇海報論文發表，研討會與會人員包括產官學研各界專家學者、工程師、學生、政府代表、非政府組織代表等總計 14,400 人以上，分別來自於 107 個不同國家。其中與本署土壤及地下水業務較為相關的學門包括水文科學(Hydrological Sciences)及土壤系統科學(Soil System Science)，相關議題詳列如下，水文科學及土壤系統科學逐日詳細議程則請詳見附件 1。

水文學(Hydrological Sciences, HS)

HS1 – General Hydrology

HS2 – Catchment hydrology

HS2.1 – General Catchment Hydrology

HS2.2 – Catchment hydrology in selected climates and world regions

HS2.3 – From observations to concepts to predictions

HS2.4 – Hydrological change: detection and prediction

HS3 – Hydroinformatics

HS4 – Hydrological Forecasting

HS5 – Water Management, Operations and Control

HS6 – Remote Sensing and Data Assimilation

HS7 – Precipitation and Climate

HS8 – Subsurface Hydrology

HS8.1 – Subsurface Hydrology – General sessions

HS8.2 – Subsurface Hydrology – Groundwater

HS8.3 – Subsurface Hydrology – Vadose zone hydrology

HS9 – Erosion, sedimentation and river processes

HS10 – Ecohydrology, Wetlands and Estuaries

HS11 – Co-organized sessions

HS12 – Short Courses in Hydrological Sciences

SSE – Special scientific events

土壤系統科學(Soil System Science, SSS)

SSS0 – General Soil Science

SSS1 – History, Education and Society of Soil Science, taxonomy

SSS2 – Land Degradation and Soil Conservation

SSS3 – Soils as Records in Time and Space

SSS4 – Soil Biology, Microbiology and Biodiversity

SSS5 – Soil Chemistry

SSS6 – Soil Organic Matter

SSS7 – Soil Physics

SSS8 – Soil Pollution and Reclamation

SSS9 – Soil, Environment and Ecosystem Interactions

SSS10 – Soils, Forestry and Agriculture

SSS11 – Metrics, Informatics and Statistics in Soils

SSS12 – Material and Methods in Soil Science

SSS13 – Co-organized sessions

SSE – Special scientific events

本次研討會中，本署發表 1 篇海報論文「臺灣地下水品質分級管理規劃(Classification Management Plan of Groundwater Quality in Taiwan)」，內容主要為規劃臺灣地下水背景水質分級指標，並評估各地下水分區及監測井之綜合分級成果。而本署參與本次會議之預期效益說明如下：

(一) 藉由會議中各國管理政策之推成果與現況，瞭解國際間地下水品質

管理發展趨勢。

(二) 掌握各國於地下水品質管理之經驗，精進我國地下水品質管理制度，並配合相關水質標準或用水需求，研擬合宜之相關地下水管理制度，確保國人用水及環境安全。

(三) 汲取先進國家環境資源管理之最新概況，以作為未來國內依環境資源分區研擬國土規劃、健全地下水資源管理政策、強化行政管理體系之參考。

二、過程

(一) 研討會

本次「2017年歐洲地球科學聯盟年會(European Geosciences Union General Assembly 2017)」國際研討會係由歐洲地球科學會(European Geosciences Union)主辦。本研討會自2005年起，每年4月固定於奧地利維也納召開，本年度會議時間為106年4月24日至28日，研討會中論文發表形式可分為口頭報告、多媒體(PICO)及海報論文展示，口頭報告於不同會議室進行各項議題之成果發表，多媒體則先以簡短的口頭發表，使聽眾快速了解數十篇論文之研究重點及主要成果，接著再以電子屏幕展示個別論文的簡報，聽眾可選擇有興趣的議題，再與作者深入討論，海報論文則每日安排不同展示主題，與會者與作者可於研討會中場休息時間相互交流。此外會議另有安排廠商參展(Exhibition)、短期課程(Short courses)、公開分組會議(Public splinter meetings)、重大爭議聯合發表與講演(Great debates, Union symposia & lectures)等開放活動，藉由公開多元的討論與溝通，為本次會議增加更多的參與機會，並激發出多樣的思維火花。

依據議題類別及本署推動業務需求，本次參與行程如表1所示，研討會現場相關照片如圖1所示。以下依照與地下水相關之發表論文，按主題歸納並分別說明其重要成果，前述各發表論文摘要按第一作者姓氏整理如附件2所示。

1. 地下水環境永續性：近年來由於全球氣候變遷、地下水超量抽取，以及土地利用型態改變，對地下水環境包括水質及水量均造成顯著衝擊，地下水環境變得更加脆弱，以往認為可自行恢復的地下水資源，有可能將永遠枯竭。也因此地下水環境永續性(sustainability)和地下水脆弱度(vulnerability)，以及其相關之評估方法，成為本年度會議地下水主題之最大重點，相關主題論文主要研究內容包含：

(1) 地下水脆弱度評估：本次會議中有多篇論文探討地下水脆弱度，並用以評估地下水環境永續性。Dams 等人於比利時 Flanders 地區進行地下水中農藥調查，並以農藥移動性與在環境中持久性作為權重，加上土壤有機質含量、土壤質地、不飽和層厚度、含水層水力傳導係數等因素，以 GeoPEARL 模式計算綜合性之地下水脆弱度，最後將計算結果繪製成比利時 Flanders 地區之地下水脆弱度地圖(vulnerability map)。van Rooyen 等人調查南非淺層地下水中氚含量，作為地下水層是否易受降雨或蒸散作用影響，進而結合氣候變遷模式標定出各地區地下水脆弱度。Song 等人則以 2012 至 2014 年韓國地下水監測水位資料，結合氣象資料，評估韓國發生乾旱事件時地下水脆弱度。Toth 等人的研究則是以匈牙利 Tihany 半島為案例，建置地下水關連生態系(groundwater-dependent ecosystems)並以數值模擬評估地下水脆弱度，進而找出發生氣候變異時最為脆弱的地下水關連生態系如濕地等，以作為預做因應措施之決策基礎。此外 Ivan 及 Madl-Szonyi 則是以匈牙利與斯洛伐克的 Gömör-Torna 喀斯特地形區為例，結合水文及地質參數評估，繪製該區域之地下水脆弱度地圖。Saks 等人則是評估了卡吉克斯坦位於天山北麓 Talgar 沖積扇地下水脆弱度，結果顯示冰河融水為該地區地下水主要補注來源，然而由於冰河持續退縮，預期將該地區可用地下水資源將持續減少。

(2) 地下水足跡：Charchousi 等人提出了以地下水足跡(groundwater footprint, GWF)作為地下水環境永續性指標。所謂地下水足跡，即代表某區域地下水出流量及使用量，與補注量之間的差異，也就是地下水平衡的結果。其計算方式如下：

$$GWF(m^2) = C \bullet A / (R - E)$$

其中 C：含水層流出量(m/d)

R：含水層補注量(m/d)

E：含水層補注河川流量(m/d)

A：區域面積(m^2)

目前地下水足跡已在希臘進行試用。

(3) 全球氣候變遷對地下水之影響：本次 EGU 會議中，全球氣候變遷(global climate change)在不同地質與地球科學領域均有相當多的討論，例如水的循環以及地質災害等。在地下水相關領域方面，也有學者加以著墨。Doveri 等人研究義大利三種典型地質之含水層，包括喀斯特地質(karst)、岩層裂隙(fractured)以及非固結地層(unconsolidated)，發現受到全球氣候變遷影響，過去二十年來其地下水通量及地下水位均呈現下降趨勢。Neumann 等人則指出，因受到全球氣候變遷影響，流入瑞士 Lugano 湖之地表逕流減少，地下水與湖水交換增加，而地下水中的磷流入量隨之增加，因而加劇 Lugano 湖的優養化現象。Verhoef 等人以 UPSCALE 計畫之高解析度全球氣候模擬器(High-resolution global climate modelling)，預估西非地區降雨、地表與地下逕流、蒸散以及土壤含水率等參數，進行地下水平衡計算，其結果並用於該地區地下水資源利用之規劃。He 等人則以 PCR-GLOBWB 水文模式，分析 1979 至 2014 年間美國加州地區乾旱對地下水之影響，其結果顯示因全球氣候變遷導致乾旱期間增加了 50%至 100%；由於乾旱期間農業及民生用水更加依賴地下水，使得地下水也恢復所需時間延長為 1.5 倍至 3.5 倍，然而乾旱期間採用適當之節水管理措施，可減少一部份之影響。

(4) 古地下水使用問題：古地下水(fossil groundwater)屬不可再生之地下水資源，目前全球在許多乾旱地區，為了擴大農業灌溉用途而不斷抽用古地下水，導致古地下水資源日漸枯竭。Bierkens 等人的研究顯示，全球因種植穀物所使用之古地下水，其影子價格(shadow price)偏低，顯示其利用效率偏低，甚至可能多數用量為不必要之浪費。Bierkens 等人進一步以印度為研究案例，指出只要適度改變作物種類，並使用節水技術，即可大幅減少古地下水的消耗量，使得有限之資源能作為永續利用。

2. 地下水水質指標與分類管理：我國目前正推動地下水水質分類與管理計畫，以地下水水質指標結合管理手段，而本次會議中也可發現部份國家也正進行地下水分類與指標研究，應可作為我國參考：

(1) Westerhoff 等人介紹了紐西蘭於 2001 年起建置的全國地下水含水層分類方法，首先全紐西蘭含水層資料數位化後納入地理資訊系統(GIS)，並在 1:250,000 比例尺之 QMAP 平台上劃分為 200 個地下水區。QMAP 依據含水層地質構造、透水性等水文地質參數，將含水層之水資源潛勢劃分為差(poor)、低(low)、中(medium)、高(high)四等級。本研究進一步指出未來紐西蘭還會持續建立全國各含水層三維空間資料，包括水力傳導係數(hydraulic conductivity)等，將使地下水環境的管理能力獲得大幅度提升。

(2) Cseko 等人介紹了研究歐盟的大型地下水研究案 KINDRA 計畫(Knowledge Inventory for Hydrogeology Research)，其前二年研究成果主要在於 HRCSYS(Harmonized Terminology and Methodology for Classification and Reporting Hydrogeology related Research in Europe)以及 EIGR(European Inventory of Groundwater Research)，其中 HRCSYS 主要用於地下水研究主題分類，EIGR 則是統合了歐盟地區地下水資源調查成果，並以資料表以及地下水資源分布圖表示。本研究進一步指示 HRCSYS 及 EIGR 的成果，將進一步用於改善和發展歐盟之地下水環境管理策略，包括擬訂水框架指令(Water Framework Directive, WFD)以及地下水指令(Groundwater Directive, GWD)。

(3) Buvaneshwari 等人研究南印度農業區域，發現地下水水質受化學肥料影響，呈現鹽化趨勢，因此建議以氯離子作為該地區地下水水質指標。

(4) Edjah 等人研究伽納 Lower Tano 河流域之地表水及地下水，並以重金屬污染指標(Heavy metal pollution index, HPI)、水中鎘濃度，以及重金屬污染指標(Heavy metal evaluation index, HEI)，作為該

地區地下水水質指標。

3. 地下水污染物：今年會議中針對地下水污染物，仍有多篇論文發表，其重要成果茲依污染物類別綜合說明如下：

(1) 硝酸鹽：本次會議中有數篇論文以地下水中之硝酸鹽污染作為主題。Stellato 等人於義大利 Alento 河流域以同位素鑑定法，研究地表水與地下水間之硝酸鹽循環，結果發現硝酸鹽經由地表逕流入滲含水層，並在河川下游與地表水進行交換。Klement 等人探討德國地下水硝酸鹽污染，並以超用氮量(kg-N/ha/year)作為指標，結果指出地下水硝酸鹽來源主要為農地過度施肥，以及高密度之禽畜養殖。Karaman 等人則是針對土耳其 Acıgöl 湖盆地，調查該地區地下水硝酸鹽污染，結果顯示其 165 組地下水樣本中硝酸鹽濃度，有 25.4%超過 10 mg/L (WHO 飲用水標準)，最高濃度達到 487 mg/L，研究並指出該地地下水硝酸鹽污染，主要與當地農業活動有關。

(2) 磷：Dürr 等人指出，農業發達地區之地下水中常有過量的氮和磷，造成地下水污染，而此種高營養鹽地下水，在湖泊、河川或海濱地區與地表水產生交換，極易引發地面水體優養化與藻華現象。

(3) 氟：Da Pelo 等人指出非洲鄉村地區居民多以地下水為飲用水源，然而東非裂谷之衣索比亞、坦尚尼亞、肯亞等諸多地區，地下水受氟污染，而氟的來源與該地區地質有關。另外 Karaman 等人指出，土耳其 Acıgöl 湖盆地南部富含氟礦物如氟磷灰石(fluorapatite)和角閃石(hornblende)，加上溫泉自斷層湧出並流經該含氟礦物地層，使該地區地下水中氟濃度偏高，平均濃度約為 1 mg/L，最高濃度達 2.9 mg/L。

(4) 農藥：Caprile 等人研究阿根廷 Pergamino 溪流域地表水及地下水中除草劑污染問題，並以嘉磷塞(glyphosate)及氨甲基磷酸(aminomethylphosphonic acid, AMPA)為標的，在地下水樣本中嘉磷塞與 AMPA 之檢出率分別為 32%及 36%，其中嘉磷塞之平均和

最高濃度分別為 0.7 及 2.3 μg/L，AMPA 之平均和最高濃度分別為 1.0 及 6.0 μg/L；另外地表水分析結果顯示，地下水中之除草劑來源即為地表水入滲。Dams 等人於比利時 Flanders 地區進行地下水中農藥調查，並將計算繪製成 Flanders 地區之地下水脆弱度地圖。Auterives 等人則以法國全國各地區農藥銷售記錄(BNVD 資料庫)與地下水監測資料(ADES 資料庫)進行比對，並提出以下對策：

a. 無壓力區域(無農藥銷售)：不需要積極因應。

b. 有壓力區域(農藥銷售量大)，且地下水受污染：應採積極對策。

c. 有壓力區域(農藥銷售量大)，但地下水未受污染：持續監測，並了解地下水未受污染之可能原因，包括地質因素以及農藥在地下環境之宿命等。

(5) 重金屬與微量元素：Mehta 等人針對義大利西北 Campello Monti 之廢棄礦場，進行地下水重金屬調查，結果顯示該地區地下水中鎳濃度偏高，最高達 304 μg/L。Mora 等人針對墨西哥東北部地區淺層地下水中重金屬及微量元素進行調查，調查項目包括 Cd、Cs、Cu、Mo、Pb、Rb、Si、Ti、U、Y 及 Zn，結果顯示並無明顯污染。

4. 地下水三維模式與人工智慧：人工智慧(artificial intelligence, AI)應用於環境資源管理及污染防治領域已有超過 20 年之歷史；地下水模式也是地下水污染調查及整治之重要輔助工具，不過受限演算能力實務上多以採用二維模式為主。近年來拜個人電腦效能長足進步，以及大數據資料庫之建立，人工智慧與地下水三維模式也持續發展，茲整理本次會議相關研究成果作為參考：

(1) 地下水三維模式：Baek 等人以韓國廢棄煤礦為研究案例，建立地下水文三維模式，並用以評估礦坑封閉之成效。De Caro 等人應用大量地質鑽探資料，建立義大利米蘭市區地下水及地層分層之三維模式，該模式目前用於評估米蘭地區每年地下水可用量。Moeck

等人提出以地下水三維模式進行地下水資源管理，並評估廢棄物掩埸、工業區等污染來源對飲用水水源之潛在影響，以便採取預防措施。Criollo 等人也提出了西班牙巴塞隆納市地下水三維模式，該模式係以 GIS 為平台，整合水文地質及地質化學參數，可以二維或三維方式進行地下水模擬，目前巴塞隆納市已應用該模式進行地下水環境管理，用於決策支援及改善管理措施。

(2) 人工智慧應用：Chung 等人以韓國濟州島為研究對象，建立可預測地下水位之人工類神經網路(artificial neural network)模式，該模式以降雨量及農業用水需求為主要參數，可準確預測濟州島 10 座地下水監測站在未來 6 個月內的水位變化。預測結果可供地方政府進行地下水使用量管制，以因應發生乾旱時，避免地下水快速枯竭。Lee 等人同樣以人工類神經網路(artificial neural network)模式，研究韓國漢江冬季水產養殖及地下水熱泵系統(groundwater heat pump system)對地下水水位變動之影響，並預測改善各項操作參數時地下水位之變動情形。

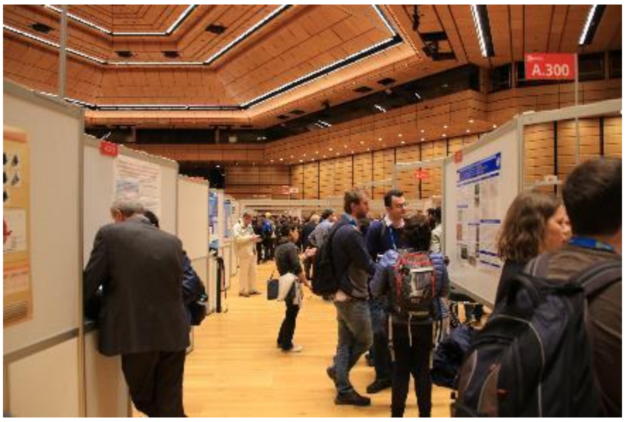
表 1　本次參與之研討會行程

日期	工作內容概要
4 月 22 日	啟程臺北－維也納
4 月 23 日	研討會註冊報到
4 月 24 日	參加 2017 年歐洲地球科學聯盟年會 （1） 氣候及土地利用變遷下區域水文行為的改變 (Hydrological change: Regional hydrological behavior under transient climate and land use conditions) （2） 水文、社會與環境變遷(Hydrology, society and environmental change) （3） 地表水地下水交換量測與模擬 Measuring and modelling surface water – groundwater interactions
4 月 25 日	參加 2017 年歐洲地球科學聯盟年會 （1） 變化世界中水資源管理與政策(Water Resources Management and Policy in a Changing World) （2） 機率地下水文學的現代挑戰(Modern challenges of stochastic groundwater hydrology: from pore to field scale)
4 月 26 日	參加 2017 年歐洲地球科學聯盟年會 （1） 水質狀況與變化趨勢評估(Assessment and interpretation of state and trends in water quality) （2） 殺蟲劑對生命、水、底泥、空氣和土壤資源的影響(The impact of pesticides in life, water, sediment, air and soil resources)
4 月 27 日	參加 2017 年歐洲地球科學聯盟年會 （1） 提升對水文過程了解的新型感測技術與資料解析方法 (Innovative sensing techniques and data analysis approaches to increase hydrological process understanding) （2） 變遷環境中的地下水資源(Groundwater resources in a

日期	工作內容概要
	changing environment) （3） Fate and transport of biocolloids and nanoparticles in soil and groundwater systems （4） 地下水脆弱度與循環(Groundwater vulnerability and circulation) [**於本議題發表本署論文海報「臺灣地下水水質分類與管理計畫」(Classification management plan of groundwater quality in Taiwan)**]
4 月 28 日	<u>參加 2017 年歐洲地球科學聯盟年會</u> （1） 應用全球尺度模式與資料於區域水資源研究 (Applying global-scale models and data in local water resources studies)」 （2） 大尺度水文學(Large scale hydrology) （3） 土壤、地下水及河川中的微量污染物和病原菌 (Micropollutants and pathogens in the soil-groundwater-river continuum: modeling and monitoring)
4 月 29 日	奧地利參訪(休假)
4 月 30 日	奧地利參訪(休假)
5 月 1 日	奧地利參訪(休假)
5 月 2 日	返程維也納－臺北
5 月 3 日	返程維也納－臺北

研討會會場

報到註冊



海報發表場地

本署論文海報

參展廠商

參展廠商

圖 1 研討會相關照片

(二) 本署海報發表

本次研討會中，本署發表 1 篇海報論文「臺灣地下水品質分級管理規劃(Classification Management Plan of Groundwater Quality in Taiwan)」，內容主要為規劃臺灣地下水背景水質分級指標，並評估各地下水分區及監測井之綜合分級成果，內容概述如下，海報如圖 2 所示。

1. 臺灣針對地面水體、河川湖泊、空氣等環境面相，皆有相關環境指標提供給民眾及政府作為一個瞭解環境現況的方式，而地下水品質方面，因為涉及層面較廣，相較於其他水體也較為複雜，故目前還未有一套針對地下水品質的環境指標。
2. 本研究將目前區域性監測井歷年持續監測 50 項水質項目進行篩選及分類，篩選共 28 項水質項目並將其區分為(1)適飲性(drinkable)、(2)鹽化(salinization)、(3)人為活動(human activity)、(4)健康影響(health influences)及(5)毒性危害(toxic)等五大項目，並依上述分類結果給予權重得分（1~5 分），綜合性比對各類水體標準之門檻值（地下水污染監測標準、飲用水水源水質標準、灌溉用水水質標準）。
3. 依據本研究建置之地下水品質指標計算方式，可計算出每口區域性監測井總得分成果，本研究將其總得分介於 0 至 1 者定義為品質優良(good)、介於 2 至 4 者定義為品質普通(ordinary)、大於 5 者則定義為品質不佳(poor)。
4. 臺灣地下水品質約有 70%為優良及普通等級，品質不佳之地區多分布於西南沿海地區，以濁水溪沖積扇及嘉南平原比例最高，分別為 47.86%及 58.29%，其地下水品質不佳原因與該地區屬農業重鎮，長期抽取地下水與過量施肥，皆導致地下水遭受鹽化並有氨氮濃度偏高等問題。
5. 本研究建置之地下水品質分級指標，可綜合性評估臺灣地下水水質狀況，其成果能有效掌握各地區地下水水質變化情形，未來可做為國土環境資源分區之重要參考依據。


European Geosciences Union General Assembly 2017
Classification management plan of groundwater quality in Taiwan
A.315
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SET
Introduction
Groundwater quality of 10 major catchments in Taiwan are monitored by Taiwan EPA for 14 years. Since 2002 till now, 50 chemicals of totally 453 regional groundwater monitoring wells has been seasonally measured. The spatial-temporal groundwater quality data has been used for calculating concentration variation trend of single well and spatial distribution of every chemicals. However, the assessment of groundwater quality should be more comprehensive and simplify for groundwater resource planning. Hence, the classification indicators of single well are evaluated in this study. A geostatistical approach is adopted for estimating indicator distribution to meet the goal of water resource management.
Table 1 Classification of major chemicals in groundwater of Taiwan
Classification | Chemical | Threshold value (mg/L) | Score | Applicable regulatory
Drinkable | Fe 0.3 | Mn 0.05 | Cu 1.0 | Zn 5.0 | Phenols 0.001 | 1 | Drinking Water Standard
Salinization | EC 750 | SO4 2- 200 | Cl- 175 | 2 | Irrigation Water Standards
Human activity | NH3-N 0.25 | TOC 10 | TDS 1250 | 3 | Groundwater Standards
Health influences | NO3-N 10.0 | F- 0.8 | 4 | Drinking Water Standard
Toxic | As 0.05 | Cd 0.005 | Cr 0.05 | Pb 0.05 | Hg 0.002 | Ni 0.1 | Benzene 0.005 | Carbon tetrachloride 0.005 | 1,4-Dichlorobenzene 0.075 | 1,2-Dichloroethane 0.005 | 1,1-Dichloroethene 0.007 | Trichloroethene 0.005 | Tetrachloroethylene 0.005 | Vinyl chloride 0.002 | 1,1,1-Trichloro-ethane 0.2 | 5 | Drinking Water Standard
Methods
According to that the major demands of groundwater in Taiwan are domestic and agriculture, the irrigation water quality standard, drinking water quality standard, and groundwater pollution monitoring standards have been used for the threshold values. Based on the influence of human health risk, monitored chemicals are divided into five groups (Table 1), including drinkable, salinization, human activity, health influences, and toxic. The score of each group is 1 to 5, respectively. The score of each groups is counted when more than one chemical averaged concentration exceed its threshold value. Total score of 0-1, 2-4, and ≧5 presents the groundwater quality is good (suitable for domestic and agricultural demand), ordinary (suitable for domestic or agricultural demand), and poor (not suitable for domestic and agricultural demand), respectively. Total scores are calculated of every single well. The spatial distribution then is established by geostatistical Kriging estimation.
Results and discussion
According to the distribution of total score in each well (Figure 1), the groundwater quality in northwestern Taiwan is better than that in southwestern catchments. Long-term pumping for irrigation demand in southwestern Taiwan has caused groundwater salinization. Over-used fertilizer also led to Nitrogen accumulation and geochemical reaction cycling. The result of geostatistical estimation also shows that the deterioration of groundwater quality in southwestern Taiwan is driven by anthrogenic activity and geogenic As problems. Fortunately, groundwater quality in most of main recharge area is still ordinary to good. Table 2 show that 47.86% and 58.29% of groundwater quality in Choshui alluvial fan and Chainan plain is poor. The usage of groundwater in these two area should be adjusted. On the contrary, groundwater resource in Hsinchu platform and Taichung basin can be regarded as advantage of urban or industry development.
Conclusion
Groundwater quality indicators can clearly show the current comprehensive situation of the groundwater environment in Taiwan and can be used as a tool for groundwater quality classification management. The indicators can coordinate with the Taiwan land planning policy in the future, and will be able to effectively grasp the changes of the national sub-regional environmental resources, which can serve as one of the important references in national land zoning according to environmental resources.
Drinkable
Salinization
Human activity
Health influence
Toxic
Example 1 score：11
Example 2 score：10
Taipei Basin
Taoyuan Platform
Lanyang Plain
Hsinchu Platform
Taichung Basin
Choshui Alluvial Fan
Penghu Island
Chainan Plain
East Rift Valley
Pingtung Plain
Good
Ordinary
Poor
Groundwater recharge area
Groundwater catchment boundary
0.0 - 0.5
0.5 - 1.0
1.0 - 3.0
3.0 - 5.0
5.0 - 6.5
6.5 - 7.5
0 25 50 km
Figure 1 Distribution of single well score and spatial estimation of groundwater quality indicator
Table 2 Area (in %) of different groundwater quality in major catchment of Taiwan
Groundwater subregion | Good(%) | Ordinary(%) | Poor(%)
Taipei Basin | 10.20 | 83.60 | 6.20
Lanyang Plain | 43.71 | 56.29 | 0.00
Taoyuan Platform | 52.21 | 47.79 | 0.00
Hsinchu Platform | 38.13 | 61.88 | 0.00
Taichung Basin | 33.67 | 66.33 | 0.00
Choshui Alluvial Fan | 0.00 | 52.14 | 47.86
Chainan Plain | 0.00 | 41.71 | 58.29
Pingtung Plain | 24.10 | 68.00 | 7.90
East Rift Valley | 95.98 | 4.02 | 0.00
Penghu Island | 0.00 | 95.99 | 4.01

圖 2 本署發表海報

三、心得與建議

(一) 心得

1. 歐洲地球科學聯盟年會,係歐洲地區地球科學學門最大的國際學術組織會議，近年定期於奧地利維也納舉辦，2017 年吸引全球超過萬名專家學者與會,觀摩與發表研究成果,為地球科學界發表研究成果及心得交流討論的重要會議,經此會議可瞭解國際間地下水資源管理、地下水文及污染調查、水資源管理及永續利用之最新發展趨勢。尤其近年來全球氣候變遷、乾旱等因素，使得全球地下水資源備受威脅，以水文及水質指標作為地下水分類及管理工具，在本年度已有紐西蘭、歐盟、印度等多國研究提出,本署亦結合計畫成果發表相關主題論文海報 1 篇，顯示我國在地下水管理方面已屬十分先進。

2. 氣候變遷及土地利用改變對地下水資源及永續性產生巨大衝擊,地下水脆弱度,以及相關新穎之評估與管理方法,為本年度會議地下水主題之最大重點之一，相關主題論文主要研究內容包含：(1)地下水脆弱度調查評估，包括比利時、南非、韓國、匈牙利、斯洛伐克、卡吉克斯坦等國家已在部份區域實施應用；(2)地下水足跡，已在希臘等國推廣試用；(3)全球氣候變遷下的永續地下水資源；(4)非可再生地下水資源，如古地下水之保護。

3. 本年度會議發表多篇地下水污染物調查研究和管理相關主題論文,主要內容及研究國家或地區包含：(1)地下水硝酸鹽氮污染問題，包括義大利 Alento 河流域、德國、土耳其 Acıgöl 湖盆地等；(2)地下水中磷污染問題；(3)地下水氟污染問題，包括東非裂谷諸國；(4)地下水農藥污染問題，包括法國、阿根廷、比利時 Flanders 地區；(5)地下水微量元素與重金屬，包括義大利、墨西哥等。

(二) 建議

1. 全球氣候變遷及乾旱等不利因素下，使得全球各國開始重視永續地下水資源管理，我國推動地下水水質分類與管理計畫，觀念及作法均屬先進。不過韓國等積極推動人工智慧及人工類神經網路，並且大規模運用地下水三維模式模擬，用於地下水資源管理及脆弱度評估，值得我國注意，並建議及早在此一領域進行研究探討。

2. 地下水環境脆弱度分析評估已在比利時、南非、韓國、匈牙利、斯洛伐克、卡吉克斯坦等國家，未來可能成為世界各國管理地下水環境品質，以及維護地下水資源永續性之重要工具，因此建議我國也應進行相關研究。

3. 本次會議有關地下水之另一重點為微量污染物的調查與因應，我國持續推動新興污染物調查，並適時納入地下水監測標準及管制標準，符此一大趨勢。另本次會議中已有德國、義大利、土耳其等國對地下水中硝酸鹽問題進行探討，建議我國在地下水硝酸鹽問題可加速推動調查研究與積極管理。

4. 本次會議中，本署發表海報論文一篇，內容係介紹我國地下水水質分類與管理計畫，經由簡要口頭報告及海報展示，與國外學者相互交流，宣揚我國地下水管理先進觀念與作法，獲得國外學者專家肯定。另外，本次會議中也有紐西蘭、歐盟、印度提出與我國類似的地下水分類作法，建議未來可再蒐集世界先進國家管理制度與分類方法，並尋求機會進行深入交流。

附件一

研討會議程

Monday, 24 Apr

HS2.2.1 Mountains and snow: Monitoring and modeling of snow

HS2.4.1 Hydrological change: Regional hydrological behaviour under transient climate and land use conditions

HS5.3 Advances in socio-hydrology

HS6.4 Remote sensing of soil moisture

HS8.1.7/ERE5.10/GM8.10/GMPV3.7 Reactive transport, mineral dissolution and precipitation in fractured and porous rock: experiments, models and field observations (co-organized)

SSS2.5/GM4.6/HS9.10/NH9.25 Connectivity in hydrology and sediment dynamics: concepts, measuring, modelling, indices and societal implications (co-organized)

SSS4.8 Carbon and nutrient cycling in biological activity hot spots in soil

SSS4.9 Media Soil and human health PICO session

SSS5.12 Chemistry of exogenous and native soil organic matter: accrual, mineralization, stabilization and management

SSS8.5 Restoration of dryland ecosystems: biogeochemistry, ecohydrology and soil processes, and current rehabilitation practices

SSS9.13/BG9.45/CL4.06/CR4.7 Soils in cold-climate regions (co-organized)

SSS10.8/BG9.6/HS9.11 Soil Erosion, hydrological processes and biological degradation in worldwide vineyards (co-organized)PICO session

SSS2.5/GM4.6/HS9.10/NH9.25 Connectivity in hydrology and sediment dynamics: concepts, measuring, modelling, indices and societal implications (co-organized)

SSS10.8/BG9.6/HS9.11 Soil Erosion, hydrological processes and biological degradation in worldwide vineyards (co-organized)PICO session

AS2.4/HS11.2/SSS9.28 Challenges of a changing Mediterranean natural environment (co-organized)PICO session

NH3.7/GM8.5/SSS2.24 Mechanics of Mass Flows (co-organized)

AS2.1/SSS9.25 Impact of Land-Surface-Atmosphere Feedbacks on Weather and Climate (co-organized)

AS2.4/HS11.2/SSS9.28 Challenges of a changing Mediterranean natural environment (co-organized)PICO session

NH1.2/AS1.6/SSS9.29 Media Atmospheric Electricity, Thunderstorms, Lightning and their effects (co-organized)

HS4.1/AS4.35/GM9.11/NH1.10 Flash floods and associated hydro-geomorphic processes: observation, modelling and warning (co-organized)

SSS10.7 Environmental processes and land managements that influence vineyard ecosystem and wine quality PICO session

AS2.3/CR6.4/OS5.5/SSS9.27 Boundary Layers in High Latitudes: Physical and Chemical Exchange Processes over Ocean-Ice-Snow-Land Surfaces (co-organized)

HS1.2 Media Hydrology, society and environmental change

HS2.1.2 On the interaction of models and hydrological knowledge: the battle of reducing uncertainty and increasing realism

HS5.2 Water resources - assessment, management, and allocation - in (semi-)arid regions

HS8.2.2 Fissured and karstified aquifers

HS9.6 Quantifying erosion, sediment and contaminant redistribution in river basins

SSS3.1 DEMs, LEMs and Palaeo DEMs: latest developments in Geosciences PICO session

SSS4.11 Role of soil biota in soil functioning and ecosystem service provision

SSS5.4 Future challenges in biochar research

SSS7.10/HS8.3.12 Innovative methods for characterizing physical soil properties and monitoring soil moisture (co-organized)PICO session

SSS8.4 Progress in remediation for soils polluted by potentially toxic elements

SSS9.14/BG9.46/CL3.13 Media Carbon sequestration in soils for mitigation, adaptation and food security: making the '4 per 1000' goal a reality and studying soils based negative emissions technologies (NETs) (co-organized)

SSS10.5 Novel soil management approaches to address the impact of agriculture on the soil system: practice and education PICO session

SSS7.10/HS8.3.12 Innovative methods for characterizing physical soil properties and monitoring soil moisture (co-organized)PICO session

G3.2/CR2.4/HS11.8/OS4.12 Fluid signatures in the hydrosphere, ocean and cryosphere from space geodesy and Earth rotation monitoring (co-organized)

SC24/HS12.2 ECS How to get your hydrology paper published – dealing with editors, reviews and revisions (co-organized)

AS2.2/SSS9.26 Air-Land Interactions (General Session) (co-sponsored by iLEAPS) (co-organized)

HS1.3 Hydrologic Dynamics, Analytics and Predictability: Physical and Data-based Approaches for Improving Hydrologic Understanding and Prediction

HS1.11 Learning from hypotheses and failures in hydrology PICO session

HS2.1.6 Measuring and modelling surface water – groundwater interactions

HS5.9/CL2.17/CR6.9/NH1.9 Water infrastructure risks under climate variability and change: role of data analysis, operating approaches, hydro-meteorological and multi-sectoral forecasts (co-organized)

SSS2.19 Get immersed in the Soil Sciences: bright ideas shared among avatars

SSS9.20/BG9.62/HS11.57 Water repellency of soil, biological and manmade materials: origin, assessment and implications (co-organized)

SSS10.12/ERE2.5 Conservation of land resources and land tenure systems (co-organized)

GM1.6/BG9.38/HS11.11/NH8.8/TS4.7 Perturbation of earth surface systems by rare events (co-organized)

NH1.5/AS4.37/CL4.19/HS11.27/SM10.9/SSS10.16 Media Hazard Risk Management of Agroecosystems and Induced Human Migration (co-organized)

SSS9.20/BG9.62/HS11.57 Water repellency of soil, biological and manmade materials: origin, assessment and implications (co-organized)

SC86/HS12.7 Using R in hydrology (co-organized)

NH8.1/SSS8.11 Environmental contamination: heavy metals, minerals, radionuclides and dusts (co-organized)

NH1.5/AS4.37/CL4.19/HS11.27/SM10.9/SSS10.16 Media Hazard Risk Management of Agroecosystems and Induced Human Migration (co-organized)

SC89/SSS13.16 The future of permafrost in a climate-changing world (co-organized)

HS1.1 Self-made sensors and unintended use of measurement equipment (poster-only session)

SSS11.4/BG9.41/NP10.5 Complexity and non-linearity in soils (co-organized)

SC96/SSS13.18 Hydrological and sediment connectivity: from concepts to experimental and modelling procedures (co-organized)

Tuesday, 25 Apr

HS5.4 Media Water Resources Management and Policy in a Changing World

HS6.3 Water Level, Storage, floods and Discharge from Remote Sensing and Assimilation in Hydrodynamic Models

HS8.1.6 Fluid dynamics, solute transport and biogeochemical reactions in porous media – new advances towards mechanistic understanding

HS9.1/GM4.9/SSS12.22 Measuring and numerical modelling of hydro-morphological processes in open-water environments (co-organized)

HS10.7/BG9.51/GM9.7 Linking river ecology, hydrology, and geomorphology for integrated river management (co-organized)

SSS1.6/AS4.51/BG9.13/CL3.06/HS11.43/NH9.22 European Environmental Policies and Sustainability (co-organized)

SSS2.10 Soils of marginal lands – definition, assessment and land use options

SSS2.22/HS9.12/NH9.24 Advances and gaps in understanding, predicting and preventing hydrological and erosional risks in fire-affected watersheds. (co-organized)

SSS4.7 Soil biodiversity in natural and agricultural ecosystems

SSS8.4 Progress in remediation for soils polluted by potentially toxic elements

SSS9.19 Fate of pollutants in soil and water/sediment systems PICO session

SSS11.6/BG9.42/NP10.7 Integrating Soil Systems Ecology into biogeochemical models (co-organized)PICO session

SSS2.22/HS9.12/NH9.24 Advances and gaps in understanding, predicting and preventing hydrological and erosional risks in fire-affected watersheds. (co-organized)

CL4.08/HS11.5 Understanding past, present and future changes in the hydrological cycle (co-organized)

IE3.6/GM1.8/AS4.50/BG9.65/CL5.26/HS11.23/SSS11.11 R's deliberate role in Earth sciences (co-organized) PICO session

SSS1.6/AS4.51/BG9.13/CL3.06/HS11.43/NH9.22 European Environmental Policies and Sustainability (co-organized)

NH4.6/SM3.10/SSS2.36 Soil liquefaction; susceptibility, hazard and mitigation measures (co-organized) PICO session

IE3.6/GM1.8/AS4.50/BG9.65/CL5.26/HS11.23/SSS11.11 R's deliberate role in Earth sciences (co-organized) PICO session

HS9.1/GM4.9/SSS12.22 Measuring and numerical modelling of hydro-morphological processes in open-water environments (co-organized)

SC10/SSS13.8 Soil mapping and process modelling at diverse scales (co-organized)

HS7.3 Media Water, climate and health PICO session

HS8.1.4 Subsurface flow and solute transport: Concepts, modelling, observations and applications of dispersion, mixing and reactive transport in heterogeneous media.

SSS1.5 Environment science, public perception, stakeholders and policy makers

SSS8.2 Emerging pollutants and soil degradation: chemical behavior and biological approaches for soil restoration

SSS12.2/GM1.9/HS11.63 Experiments in Earth Surface Processes - From understanding to quantification (co-organized)

SSS12.13/BG9.26 Innovative analytical methods and hyphenated techniques in soil analysis (co-organized) PICO session

SSS12.2/GM1.9/HS11.63 Experiments in Earth Surface Processes - From understanding to quantification (co-organized)

SC73/HS12.6 Opinion papers in hydrology: Why and how (co-organized)

GM11.1/SSS2.33 Aeolian Processes and Landforms (co-organized)

GM1.1/EOS20/CL5.18/SSS13.1 Beyond the case study: Concepts in Earth Sciences (co-organized)

SC42/SSS13.14 Measurement and interpretation of redox potentials in soils and sediments (co-organized)

DM20/SSS ECS Division meeting for Soil System Sciences (SSS) (co-organized)

HS2.1.4 Catchment Organisation, Similarity, and Evolution

HS2.4.4 Water, droughts, and biosphere-atmosphere interactions under climate change and variability

HS5.8/ERE3.8 Hydropower and other renewable sources of energy for a sustainable future: modelling and management issues (co-organized)

HS6.2 The Third Pole Environment - hydrometeorological processes and ancient human activity

HS7.6/AS1.10/NP10.3 Precipitation variability: from drop scale to lot scale (co-organized)PICO session
HS8.2.6 Modern challenges of stochastic groundwater hydrology: from pore to field scale
SSS1.2/EOS22 Soil Science Education (co-organized)
SSS2.4 Gully and rill erosion: recent research progress
SSS7.6/HS8.3.11 Soil water Infiltration. Measurements, assessment and modeling (co-organized)
SSS8.3 Interdisciplinary approaches to improve bioremediation and biomining techniques and reduce soil pollution PICO session
SSS9.5/NH3.13 Landslide early warning systems: monitoring systems, rainfall thresholds, warning models, performance evaluation and risk perception. (co-organized)
SSS12.5/HS7.10 Rainfall simulators as a tool in Soil Science, Geomorphology and Hydrology research and teaching (co-organized)
SSS12.5/HS7.10 Rainfall simulators as a tool in Soil Science, Geomorphology and Hydrology research and teaching (co-organized)
SSS7.6/HS8.3.11 Soil water Infiltration. Measurements, assessment and modeling (co-organized)
NH9.5/AS4.32/CL2.27/HS11.38/SM3.9/SSS13.3 Natural Hazard and Risk Assessment in Developing Countries (co-organized) PICO session
GM6.4/CL1.16/SSS3.10 Palaeoenvironmental evolution, connectivity and geomorphological dynamics in dryland areas: New approaches, challenges, pros and cons (co-organized)
NH9.5/AS4.32/CL2.27/HS11.38/SM3.9/SSS13.3 Natural Hazard and Risk Assessment in Developing Countries (co-organized) PICO session
SC61/SSS13.15 International Decade of Soils: Ideas for outreach activities (co-organized)
HS5.6/SSS9.33 Catchment Science and Management: Nature-Based Solutions for rural and urban environments (co-organized) PICO session
HS8.1.3 Model Uncertainties, Parameter Estimation, and Data Assimilation in Surface and Subsurface Hydrology
HS10.10 Groundwater - Surface Water interactions: biogeochemical and ecological processes
SSS1.4 Soil, Art, Culture, and History
SSS2.18 New challanges in Land Degradation and Restoration research
SSS8.7 Novel sorbent materials for environmental remediation PICO session
HS5.6/SSS9.33 Catchment Science and Management: Nature-Based Solutions for rural and urban environments (co-organized) PICO session
HS5.1 Hydrology & Society: Transdisciplinary approaches to hydrology and water resources management
HS9.9 Protection against hydrologically triggered soil failure: new perspectives in eco-engineering
SSS7.12/BG9.24/HS8.3.13/SSP3.12 Microenvironments in soils and sediments - linking concepts,

experiments and models (co-organized)
SSS7.12/BG9.24/HS8.3.13/SSP3.12 Microenvironments in soils and sediments - linking concepts, experiments and models (co-organized)
GI3.6/EMRP4.18/ERE5.9/SSP1.7/SSS12.27 Geoscientific Underground Labs and Test Sites (co-organized)

Wednesday, 26 Apr

HS2.1.1 Media Hydrological extremes: from droughts to floods
HS2.2.2/AS4.15/CL2.07/CR3.6/NH1.16 Mountains and snow: Advances in large-scale land surface, hydrological and climate modelling (co-organized) PICO session
HS4.5/NH1.13 Operational forecasting and warning systems for natural hazards: challenges and innovation (co-organized) PICO session
HS5.5 Assessment and interpretation of state and trends in water quality
HS6.1 Open session on remote sensing applications in hydrology and climate studies
HS7.5/NH1.8 Hydroclimatic extremes under change: advancing the science and implementation in hazard prevention and control (co-organized)
HS8.2.7 Estimation and application of groundwater ages and mean residence times
SSS2.1 Land Degradation and Development. A State-of-the-Art
SSS4.17/BG9.9 Biological soil crusts: their history, diversity, functional roles and threats (co-organized) PICO session
SSS6.2/BG9.11 Soil organic matter turnover: from molecules to ecosystems and back again (co-organized)
SSS7.2/HS8.3.10 Preferential flow and mass transfers in vadose zone (co-organized)
SSS9.15 Impact of agriculture on soil ecosystem services
SSS7.2/HS8.3.10 Preferential flow and mass transfers in vadose zone (co-organized)
US1/AS4.52/BG9.67/CL4.20/SSS0.4 Vegetation-climate interactions across time scales (co-organized)
US1/AS4.52/BG9.67/CL4.20/SSS0.4 Vegetation-climate interactions across time scales (co-organized)
NH7.1/SSS2.26 Spatial and temporal patterns of wildfires: models, theory, and reality (co-organized)
NH3.3/GI3.11/SSS2.27 Characterizing and monitoring landslide processes using remote sensing and geophysics (co-organized)
GM1.3/EOS19/SSS3.12 Geodiversity and Geoheritage (co-organized)
GI1.1/EMRP4.16/SSS12.25 Applications of Data, Methods and Models in Geosciences (co-organized)
US1/AS4.52/BG9.67/CL4.20/SSS0.4 Vegetation-climate interactions across time scales (co-organized)
HS8.2.3/ERE6.7 Thermal and mechanical processes and energy storage in porous and fractured

aquifers (co-organized)

HS9.8/GM9.8 Experimental and numerical investigation of river confluence hydrodynamics and morphodynamics (co-organized)

HS10.1/GM12.7/OS2.4 Estuarine processes (co-organized)

SSS5.6 Peatlands and wetlands in the tropics and beyond: biogeochemistry, ecology, and carbon cycle

SSS6.5/BG9.55 Natural and pyrogenic organic carbon and nitrogen in soils: Function, fate, analytical challenges and how this relates to the concept of humic substances (co-organized)PICO session

SSS12.1/HS11.62 Advancing proxies in the critical zone for deciphering time-dependent processes in weathering profile and natural and anthropognenic fingerprinting of water (sponsored by European Association of Geochemistry) (co-organized)

SSS12.11/GM3.7 Learning from spatial data: unveiling the geo-environment through quantitative approaches (co-organized)

SSS12.1/HS11.62 Advancing proxies in the critical zone for deciphering time-dependent processes in weathering profile and natural and anthropognenic fingerprinting of water (sponsored by European Association of Geochemistry) (co-organized)

HS1.10 How my water research made the news PICO session

HS8.2.5 Hydrogeology of coastal zones: processes, consequences and potentials

HS9.7/GM4.7 Investigation of sediment transport processes due to geophysical flows (co-organized)

HS10.5 New methods, stable isotope techniques and physical principles in ecohydrology

SSS2.20/HS11.51 Innovation and new challenges in sharing research results and knowledge of soil and water resources: experiences on strategic thinking, technologies and collaborative work. (co-organized) PICO session

SSS5.16 Media Designing biochars to react with N species and mechanisms of nutrient enhancement

SSS6.8/BG9.56 The impact of soil organic carbon loss on environmental services (co-organized)

SSS7.8/BG9.10/HS11.53 Media The impact of pesticides in life, water, sediment, air and soil resources (co-organized)

CL1.25/AS4.26/HS2.4.5 Flood and weather extremes of the past (co-organized)

CL1.01/AS4.9/CR1.12/HS7.9/OS1.13 Into the Anthropocene; Observing and interpreting the historical record of temperature and other climate indicators (co-organized)

CL4.07/AS1.14/BG9.18/CR1.7/HS11.3 Media Mountain climates: processes, change and related impacts (co-organized)

SSS2.20/HS11.51 Innovation and new challenges in sharing research results and knowledge of soil and water resources: experiences on strategic thinking, technologies and collaborative work. (co-organized) PICO session

SSS7.8/BG9.10/HS11.53 Media The impact of pesticides in life, water, sediment, air and soil resources (co-organized)

GM7.3/CL1.09/SSS3.11 Media Geoarchaeology: Human impact, adaptation and response to climatic and environmental change from the past to the present (co-organized)

BG2.16/CL5.24/SSS9.40 Response of terrestrial ecosystems to climate change: Learning from experimental manipulations and natural gradients (co-organized)

HS1.4 (Ir-)relevant scales in hydrology: Which scales matter for water resources management?

HS2.2.3 Lowlands: A hydrologic challenge in the global environmental change eraPICO session

HS10.8 Peatland Hydrology

SSS5.17 General Soil Chemistry: from basic research to environmental aspects to food security

SSS10.2 Organic Farming and Soil management

NH3.1/HS2.3.8 Landslide hydrology: from hydrology to pore water pressure and slope deformation (co-organized)

GM3.3/SSS3.13/TS4.6 Modelling Earth surface processes and geomorphic flows: methods and validation (co-organized)

HS7.4 Climatic variability and the hydrological cycle

SSS9.17/CL2.10 Land Use and Climate Change Impact on Grasslands and Wetlands: a Pedological, Hydrological, Biological and Geomorphological Approach (co-organized)

GI1.3/AS4.41/CL5.17/EMRP4.39/HS11.7/NH6.9/SM5.9 Environmental sensor networks (co-organized)

GI3.8/HS11.10/SSS12.19 Broadband and multi/hyper-spectral IR sensing techniques for the retrieval of land surface temperature and emissivity; IR sensing for environmental studies (i.e geo-hazards, agriculture, atmosphere and urban) (co-organized)

GM3.2/GI2.12/GMPV6.4/HS11.13/NH8.9/SSS12.24 High Resolution Topography in the Geosciences: Methods and Applications (co-organized)

NH9.7/AS4.33/CL2.28/HS11.34 Urban Resilience Studies –Risk Mapping (co-organized)

SC52/HS12.5 Short course on Hydrological Forecasting (co-organized)

GI3.8/HS11.10/SSS12.19 Broadband and multi/hyper-spectral IR sensing techniques for the retrieval of land surface temperature and emissivity; IR sensing for environmental studies (i.e geo-hazards, agriculture, atmosphere and urban) (co-organized)

GM3.2/GI2.12/GMPV6.4/HS11.13/NH8.9/SSS12.24 High Resolution Topography in the Geosciences: Methods and Applications (co-organized)

Thursday, 27 Apr

HS1.15 Recent advancement in estimating global, continental and regional scale water balance components PICO session

HS2.3.1 Innovative sensing techniques and data analysis approaches to increase hydrological process understanding

HS7.2/AS1.9/CL2.15/NH1.14/NP10.1 Precipitation uncertainty and variability: observations, ensemble simulation and downscaling (co-organized)

HS8.2.1 Groundwater resources in a changing environment

HS8.3.1 Vadose zone hydrology: General Session

HS10.3/BG9.4/SSS9.34 General Ecohydrology (co-organized)

SSS1.7/AS4.49/CL5.20/HS11.44/NH9.21 “Lighthouse” examples, illustrating soil relevance for the UN Sustainable Development Goals (SDG’s) (co-organized)PICO session

SSS2.1 Land Degradation and Development. A State-of-the-Art

SSS7.7/HS8.3.14 Multi-scale structure-property relationships for porous media: how pore-scale processes can help describe flow and transport at the larger scale? (co-organized)

SSS9.3 Fire impacts on the Ecosystems (including SSS Division Outstanding ECS Award Lecture)

SSS11.4/BG9.41/NP10.5 Complexity and non-linearity in soils (co-organized)

NP5.3/AS1.2/HS4.8 Advances in statistical post-processing for deterministic and ensemble forecasts (co-organized)

SSS7.7/HS8.3.14 Multi-scale structure-property relationships for porous media: how pore-scale processes can help describe flow and transport at the larger scale? (co-organized)

NH1.3/HS11.25 Flood risk and uncertainty (including Plinius Medal Lecture) (co-organized)

SSS1.7/AS4.49/CL5.20/HS11.44/NH9.21 “Lighthouse” examples, illustrating soil relevance for the UN Sustainable Development Goals (SDG’s) (co-organized)PICO session

HS10.3/BG9.4/SSS9.34 General Ecohydrology (co-organized)

BG2.8/CL3.14/SSS9.38 Terrestrial ecosystem responses to global change: integrating carbon, nutrient, and water cycles in experiments and models (co-organized)

BG2.19/SSS10.19 Forests and the methane and nitrous oxide cycles (co-organized) PICO session

SC8/GM13.5/SSS13.7 Modelling soilscape development (co-organized)

HS2.3.5 Water quality at the catchment scale: measuring and modelling of nutrients, sediment and eutrophication impacts

HS7.8 Precipitation and Urban Hydrology

HS8.1.5 Fate and transport of biocolloids and nanoparticles in soil and groundwater systems

SSS4.16 Unravelling soil-biota interactions using micro-scale analysesPICO session

SSS7.3/HS8.3.8 Challenges in soil physics research (co-organized)

SSS9.4/HS11.54/NH1.20 Threats and potentials in urban and peri-urban areas: soil and water degradation, ecosystem services and risk management (co-organized)

SSS7.3/HS8.3.8 Challenges in soil physics research (co-organized)

SSS9.4/HS11.54/NH1.20 Threats and potentials in urban and peri-urban areas: soil and water degradation, ecosystem services and risk management (co-organized)

GM6.2/BG9.43/SSS9.36 Biogeomorphology: conceptualising and quantifying processes, rates and feedbacks (co-organized)

HS1.5 Advances in Sensitivity and Uncertainty Analysis of Earth and Environmental Systems Models
HS4.2/NH1.11 Predictability, predictive uncertainty estimation and decision-making in hydrologic forecasting (co-organized)
HS5.10 Hydrological Sciences and Water Footprint Assessment for monitoring and achieving the Sustainable Development Goals PICO session
HS7.1/AS1.11/NH1.15/NP10.11 Precipitation: from measurement to modelling and application in catchment hydrology (co-organized)
HS8.2.4 Groundwater vulnerability and circulation
HS10.2 Lakes and inland seas in a changing environment
SSS2.16/GM7.7/HS11.50 Agricultural terraces of the world. Their pedological, geomorphological and hydrological role (co-organized) PICO session
SSS4.5/BG9.57/CL2.12 Plant-soil-microbial interactions under global change (co-organized)
SSS9.2 Soil quality and health in agriculture areas: impact of current and novel management practices
SSS10.6/HS5.12 Irrigated agriculture: Natural Resources Management for the sustainability of the terrestrial ecosystem maintaining productivity (co-organized)
SSS10.6/HS5.12 Irrigated agriculture: Natural Resources Management for the sustainability of the terrestrial ecosystem maintaining productivity (co-organized)
GM3.2/GI2.12/GMPV6.4/HS11.13/NH8.9/SSS12.24 High Resolution Topography in the Geosciences: Methods and Applications (co-organized)
NH1.1/AS4.28/HS11.24 Extreme meteorological and hydrological events induced by severe weather and climate change (co-organized)
SSS2.16/GM7.7/HS11.50 Agricultural terraces of the world. Their pedological, geomorphological and hydrological role (co-organized) PICO session
SC29/HS12.3 Hydroinformatics for hydrology: geostatistical modelling (co-organized)
BG2.12/SSS5.18 Biogeochemistry of peatlands and lakes (co-organized)
GM3.2/GI2.12/GMPV6.4/HS11.13/NH8.9/SSS12.24 High Resolution Topography in the Geosciences: Methods and Applications (co-organized)
HS1.9/NH1.18 Media Hydrological risk under a gender and age perspective (co-organized)PICO session
HS1.13 Towards integrated process understanding using hydrological observatories
HS4.4 Drought and water scarcity: monitoring, modelling and forecasting to improve hydro-meteorological risk management
HS8.2.8 Innovative methods for the quantification of processes in the sub-surface
SSS2.8/BG9.44 Soil quality assessment in degraded ecosystems: Global advances and challenges (co-organized) PICO session

SSS9.8/BG9.8/GM6.5/NH9.26 Coevolution of soils, landforms and vegetation: patterns, feedbacks and ecosystem stability thresholds (co-organized)

NH1.6/AS1.4/HS4.9 Coupled atmosphere-hydrological modeling for improved hydro-meteorological predictions (co-organized)

BG2.16/CL5.24/SSS9.40 Response of terrestrial ecosystems to climate change: Learning from experimental manipulations and natural gradients (co-organized)

GM2.1/CL5.02/SSS12.23 Advances in the use of cosmogenic nuclides and the quantification of landscape evolution (co-organized)

ERE3.7/HS5.11 Renewable energy and environmental systems: modelling, control and management for a sustainable future (co-organized)

GI1.2/AS4.47/BG9.20/ERE1.8/HS11.9/NH8.4/OS4.11/SSS8.12 Geoscience processes related to Fukushima and Chernobyl nuclear accidents (co-organized)

GI1.2/AS4.47/BG9.20/ERE1.8/HS11.9/NH8.4/OS4.11/SSS8.12 Geoscience processes related to Fukushima and Chernobyl nuclear accidents (co-organized)

NH3.2/SM8.6/SSS9.30 Mechanisms and processes of landslides in seismically or volcanically active environments (co-organized)

Friday, 28 Apr

HS1.12 Applying global-scale models and data in local water resources studies

HS2.1.3 Media Large scale hydrology

HS2.3.3 Controls of non-stationary catchment response and spatial water quality dynamics

HS3.2/NH1.19 Spatio-temporal and/or geostatistical analysis of hydrological events, extremes, and related hazards (co-organized)

HS4.6/CL3.02 From sub-seasonal forecasting to climate projections: predicting hydrologic extremes and servicing water managers (co-organized)

HS7.7/NH1.17 Hydroclimatic and hydrometeorologic stochastics: Extremes, scales, probabilities (co-organized) PICO session

SSS2.3/HS11.46 The use of check dams for soil restoration at watershed level: resolving or generating hydrological, soil and environmental problems? (co-organized)

SSS6.7/BG9.29/GM8.9 Lateral transport of soil organic carbon: the role of erosion/deposition, land use changes, forest fires and other disturbances (co-organized)PICO session

SSS9.7/CL5.21/GM7.8/HS11.55 Soil Erosion, Land Use and Climate Change: mapping, measuring, modelling, and societal challenges (co-organized)

SSS10.1 The impact of grazing on land degradation: Identifying problems, causes and solutions from a global perspective

SSS12.8 Soil mapping, classification, and process modelling for sustainability

ERE3.7/HS5.11 Renewable energy and environmental systems: modelling, control and management for a sustainable future (co-organized)

AS4.16/BG9.2/CL2.14/HS11.1 Stable isotopes in the atmosphere - from vapor to precipitation (co-organized)

GI1.2/AS4.47/BG9.20/ERE1.8/HS11.9/NH8.4/OS4.11/SSS8.12 Geoscience processes related to Fukushima and Chernobyl nuclear accidents (co-organized)

GM4.2/HS11.14/NH3.16/SSS9.35 Erosion and Sedimentation in Mountain Landscapes (co-organized)

GM9.1/HS11.18/SSP3.5 Fluvial Geomorphology Across Scales (co-organized)

NH6.1/CR2.7/GI2.8/HS11.29/SM5.7/SSS12.20 Application of remote sensing and Earth-observation data in natural hazard and risk studies (co-organized)

SSS2.3/HS11.46 The use of check dams for soil restoration at watershed level: resolving or generating hydrological, soil and environmental problems? (co-organized)

SSS9.7/CL5.21/GM7.8/HS11.55 Soil Erosion, Land Use and Climate Change: mapping, measuring, modelling, and societal challenges (co-organized)

SC19/HS12.1 ECS Meet the Expert in Hydrology: Is research at different spatial scales connected? (co-organized)

CL1.21/BG9.59/OS2.10/SSP2.8/SSS3.15 Past climate - isotopic and multi-proxy continental and shallow marine records (co-organized)

BG2.7/SSS6.13 Peatlands and the Carbon Cycle (co-organized)

GI1.2/AS4.47/BG9.20/ERE1.8/HS11.9/NH8.4/OS4.11/SSS8.12 Geoscience processes related to Fukushima and Chernobyl nuclear accidents (co-organized)

GM4.2/HS11.14/NH3.16/SSS9.35 Erosion and Sedimentation in Mountain Landscapes (co-organized)

BG2.3/CL2.31/SSS10.17 Media Forest Management under Climate Change (co-organized)

NH6.1/CR2.7/GI2.8/HS11.29/SM5.7/SSS12.20 Application of remote sensing and Earth-observation data in natural hazard and risk studies (co-organized)

BG1.9/SSS13.11 Interdisciplinary session on the global Phosphorus cycle (co-organized)PICO session

SC17/SSS13.13 Imaging and image processing of biogeochemical and structural characteristics in soil microenvironments (co-organized)

HS1.6 Data Assimilation for Integrated Hydrological Models and Earth System Models

HS2.2.4/CR4.5 Monitoring and modelling water flow paths, supply and quality in a changing mountain cryosphere (co-organized)PICO session

HS2.3.6 Micropollutants and pathogens in the soil-groundwater-river continuum: modeling and monitoring

HS3.1 Hydroinformatics: computational intelligence, systems analysis, optimisation, data science and data-driven modelling of social-hydrologic systems

SSS3.5 Geochemical mapping at all scales: evidence from soil, sediment, water and plants

SSS11.5/ESSI4.10/HS11.61/NH9.23 Communication of uncertain information in earth sciences: data, models and visualization (co-organized) PICO session

ERE4.1/EMRP4.15/HS11.6/TS2.5 Mechanics and flows in shale rocks: properties and processes (co-organized)

SSS11.5/ESSI4.10/HS11.61/NH9.23 Communication of uncertain information in earth sciences: data, models and visualization (co-organized) PICO session

BG2.12/SSS5.18 Biogeochemistry of peatlands and lakes (co-organized)

BG4.3/SSS5.20 Biogeochemistry, ecohydrology, and land-use in the tropics and subtropics (co-organized)

BG2.8/CL3.14/SSS9.38 Terrestrial ecosystem responses to global change: integrating carbon, nutrient, and water cycles in experiments and models (co-organized)

SC16/SSS13.12 Accessing and using global soil data (co-organized)

HS2.1.5 Evapotranspiration: from measurement to modelling and application in catchment hydrology

HS2.3.2 Isotope and tracer methods: flow paths characterization, catchment response and transformation processes

HS4.3/AS4.36/NH1.12 Ensemble hydro-meteorological forecasting (co-organized)

HS8.1.2 Hydrogeophysics PICO session

SSS2.23 Salt affected soils: monitoring, risk assessment and effects on plants

SSS7.4/AS4.7/BG9.32 Production and transport of gases in the soil: measurements and modelling (co-organized)PICO session

SSS9.21 Nature-based solutions in land and water management for hydro-meteorological risk reduction and climate change adaptation

SSS12.6/GI2.13/GM3.9 Unmanned Aerial Systems: Platforms, Sensors and Applications in Soil, Agriculture and Geosciences (co-organized) PICO session

GM9.5/BG9.50/HS11.22/SSS2.28 Interactions of geomorphology, dams and flood hazard (co-organized)

NH6.3/AS4.43/GI2.10/HS11.31/SM5.8/SSS12.21 The use of Remotely Piloted Aircraft Systems (RPAS) in monitoring applications and management of natural hazards (co-organized)

SSP3.13/GM9.10/HS11.41 Sedimentological aspects of supercritical flows: Upper flow-regime structures, bedforms and fluid mechanics (co-organized)

GM9.5/BG9.50/HS11.22/SSS2.28 Interactions of geomorphology, dams and flood hazard (co-organized)

GM4.1/BG9.35/GMPV2.12/SSS2.34 Coupling chemical weathering and physical erosion: Insights from geomorphic and geochemical studies (co-organized)

BG2.10/SSS9.37 Greenhouse gases balance and management in natural and anthropogenic boreal landscapes (co-organized) PICO session

NH6.3/AS4.43/GI2.10/HS11.31/SM5.8/SSS12.21 The use of Remotely Piloted Aircraft Systems (RPAS) in monitoring applications and management of natural hazards (co-organized)

SC12/SSS13.10 Fire effects on soils and Ecosystems (co-organized)
SC90/SSS13.17 Reading soils from the Past (co-organized)
SSS3.4 Media Geomorphological and (palaeo-) pedological records of natural environmental factors and human impact
BG1.5/CL2.33/HS6.6 Media Climate extremes, biosphere and society: impacts, remote sensing, and feedbacks (co-organized)PICO session
GM4.3/HS11.15/NH8.12/SSS2.30 Hillslope and fluvial denudation, source-to-sink fluxes and sedimentary budgets under changing climate and other perturbations (co-organized)
GM6.3/BG9.37/HS11.16 Vegetated rivers: relationships between riparian vegetation, instream wood and fluvial processes, hazards and management. (co-organized) PICO session
GM7.2/ERE2.4/HS11.17/OS2.6 Media Sustainable management of river deltas under pressure (co-organized)
NH1.7/CL2.23/HS11.28 Addressing the challenge of compound events, multi-risk modelling and cross-risk assessment methods (co-organized)
NH3.11/GM8.4/SSS2.25 Rockfalls, rockslides and rock avalanches (co-organized)
GM4.3/HS11.15/NH8.12/SSS2.30 Hillslope and fluvial denudation, source-to-sink fluxes and sedimentary budgets under changing climate and other perturbations (co-organized)
NH6.4/BG9.34/CL2.24/HS11.32 Assessment of climate hazards’ impact on natural and cultural environment: Remote sensing and GIS applications (co-organized)
GM6.2/BG9.43/SSS9.36 Biogeomorphology: conceptualising and quantifying processes, rates and feedbacks (co-organized)

附件 2

關切議題摘要與發表資料

Geophysical Research Abstracts
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Improving the consideration of hydrogeological characteristics to assess the contamination groundwater by pesticides at national scale (France)

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According to the European Water Framework Directive, Member States have to conduct study of anthropogenic pressure and its impact on the status of water bodies, and to implement programs of measures in order to reverse any significant and sustained upward trend in the concentration of any pollutant. Focused on pesticides in groundwater, the aim of this work is to propose new tools to the stakeholders to identifying groundwater bodies presenting a risk of not achieving « good chemical status ».

Several parameters control the transfer of a pesticide from the soil to the groundwater: climate conditions (i.e. recharge), soil and hydrogeological characteristics, pesticides physico-chemical properties. The issues of this study are (1) to take account of hydrogeology context, besides soil and pesticide physico-chemical properties relatively well studied as in registration procedure; (2) to work at national scale which involve to consider variability of land uses and practices, (hydro)geology and climate conditions.

To overcome difficulties, this study proposes to identify, when data make it possible, the main driver (hydrogeology or pesticides properties) which explains transfer of pesticides into groundwater at the water body scale. This aspect is particularly innovative as, to date, hydrogeology contexts are usually not considered. Thus, for instance, timeframe of transfer in the unsaturated zone is also considered.
Despite work being performed for several substances with contrasted physico-chemical properties, the outcome will be a classification of substances in different groups according to their chemical properties and their potential occurrence in groundwater.

The work is based on existing data only. From French databases, BNVD (French national database of the sales of pesticides) and ADES (national French data base on groundwater resources gathering), we are able to link pesticides use and groundwater impact. As a first step, several specific pesticides were selected as study case and lead to distinguish groundwater bodies as:
- Groundwater bodies where pressure cannot be evaluated ;
- Groundwater bodies with no pressure (sale) ;
- Groundwater bodies where pressure (sale) lead to an impact (quantification of the specific substance) ;
- Groundwater bodies where there is a pressure (sale) but no impact which means (1) geological conditions offer a natural protection of groundwater quality or (2) the transfer time into groundwater is longer than the observation period or (3) the fate of pesticides lead to a limited transfer.

From the different maps and the pesticides studied, final results would be to classify groundwater bodies as:
- The main driver is hydrogeology: whatever the substance i.e. whatever the pesticide properties, impacts on groundwater quality are similar. Either, geological conditions protect the groundwater resources, pesticides do not transfer to groundwater or, there is no natural protection, whatever the substance, it transfers to groundwater.
- Geological conditions are not the main driver but the pesticide properties do. Therefore, depending on pesticides physico-chemical properties, substances will transfer to groundwater or not. A classification of substances in several groups according there properties (DT50 and Koc) will be performed.

The main expected outcome of this project is the establishment of methodology of characterization of the link between pressure and impact, at national scale. Final results would provide operational tools to the stakeholders to go further in the pressure and impact analysis of the pesticide in groundwater to improve the risk evaluation and adapt program of measures to reach the “good chemical status” of groundwater bodies.

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Three-dimensional hydrogeologic modelling to simulate groundwater inflow at an abandoned underground coal mine in Korea

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The safety and environmental concerns should be addressed for sustainable mining operations, and one of the key issues is the prediction of the groundwater flow into underground mine workings. Prediction of the groundwater inflow requires a detailed knowledge of the geologic conditions, including the presence of major faults and other geologic structures at the mine site. The hydrologic boundaries and depth of the phreatic surface of the mine area, as well as other properties of the rockmass, are also provided. Various numerical models have been applied to develop hydrogeologic models at mine sites, and the MINEDW by Itasca is one of those groundwater flow model codes developed to simulate the groundwater flow related to mining.
Mine sealing is one of the usual methods to control mine water at abandoned mines. An experimental program has been undertaken to provide a practical procedure for sealing abandoned coal mines in Korea. Two abandoned coal mines were selected, and extensive geological and geophysical surveys were performed. Field hydraulic tests, such as pumping tests and packer tests, had also been conducted to measure the hydraulic conductivities of the rock mass. In this study, constructing three-dimensional hydrogeologic models of the study area are essential for design and installation of the stable adit-plug system. With the complete 3D model constructed, the rate of mine water rebound after the installation of the adit-plug system can be hypothesized. The maximum water pressure affecting the stability of the plug, and the long-term seepage problems, can also be estimated.

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The shadow price of fossil groundwater

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The expansion of irrigated agriculture into areas with limited precipitation and surface water during the growing season has greatly increased the use of fossil groundwater (Wada et al., 2012). As a result, the depletion rate of fossil groundwater resources has shown an increasing rate during the last decades (Wada et al, 2010; Konikow, 2011; Wada et al., 2012; De Graaf et al. 2015; Ritchy et al., 2015). Although water pricing has been used extensively to stimulate efficient application of water to create maximum value (e.g. Medellín-Azuara et al., 2012; Rinaudo et al., 2012; Dinar et al., 2015), it does not preclude the use of non-renewable water resources. Here, we use a global hydrological model and historical crop production and price data to assess the shadow price of non-renewable or fossil groundwater applied to major crops in countries that use large quantities of fossil groundwater. Our results show that shadow prices for many crops are very low, indicating economically inefficient or even wasteful use of fossil groundwater resources. Using India as an example, we show that small changes in the crop mix could lead to large reductions in fossil groundwater use or alternatively, create additional financial means to invest in water saving technologies. Our study thus provides a hydro-economic basis to further the sustainable use of finite groundwater resources.

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Impacts of land-use and soil properties on groundwater quality in the hard rock aquifer of an irrigated catchment: the Berambadi (Southern India)

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Irrigated agriculture has large impacts on groundwater resources, both in terms of quantity and quality: when combined with intensive chemical fertilizer application, it can lead to progressive groundwater salinization. Mapping the spatial heterogeneity of groundwater quality is not only essential for assessing the impacts of different types of agricultural systems but also for identifying hotspots of water quality degradation that are posing a risk to human and ecosystem health.

In peninsular India the development of minor irrigation led to high density of borewells which constitute an ideal situation for studying the heterogeneity of groundwater quality. The annual groundwater abstraction reaches 400 km3, which leads to depletion of the resource and degradation of water quality. In the agricultural Berambadi catchment (84km2, Southern India, part of the environmental observatory BVET/ Kabini CZO) the groundwater table level and chemistry are monitored in ∼200 tube wells. We recently demonstrated that in this watershed, irrigation history and groundwater depletion can lead to hot spots of NO_3 concentration in groundwater, up to 360 ppm (Buvaneshwari et al., 2017). Here we focus on the respective roles of evapotranspiration, groundwater recycling and chemical fertilizer application on chlorine concentration [Cl] in groundwater.

Groundwater [Cl] in Berambadi spans over two orders of magnitude with hotspots up to 380 ppm. Increase in groundwater [Cl] results from evapotranspiration and recycling, that concentrates the rain Cl inputs ("Natural [Cl]") and/or from KCl fertilization ("Anthropogenic [Cl]"). To quantify the origin of Cl in each tube well, we used a novel method based on (1) a reference element, sodium, originating only from atmosphere and Na-plagioclase weathering and (2) data from a nearby pristine site, the Mule Hole forested watershed (Riotte et al., 2014). In the forested watershed, the ranges of Cl concentration and Na/Cl molar ratio are 9-23 ppm and 2.5-6, respectively, while in Berambadi Na/Cl drops down to 0.3 due to the addition of KCl-chlorine.

Natural [Cl] estimated in Berambadi groundwater was on average 44 ppm (from 8 to 170 ppm). This means that on average, evapotranspiration and recycling in Berambadi groundwater was 2 to 4 times greater than evapotranspiration in the nearby forest. Hot spots (8 to 20 times forest ET) were all located along the stream, associated with Vertisols and long irrigation history. Anthropogenic [Cl] ranged from 0 to 270 ppm, accounting for up to 90% of the total Cl in some wells. Hotspots were also associated with long irrigation history, however extreme values were found in the severely depleted groundwater area, associated with the nitrate hotspot.

Our approach allowed to quantify the respective contributions of groundwater recycling and chemical fertilizer inputs to the progressive salinization of groundwater. Using the AICHA model coupling the crop model STICS and a groundwater model under different climate scenarios, we show that the development of contamination hot spots can be mitigated by adequate management options.

Keywords: Groundwater quality; salinization; agriculture; hot spots

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Variation in glyphosate and AMPA concentrations of surface water and groundwater

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The presence of pesticides in various environmental matrices indicate that the soil's ability to function as a bio-physical-chemical reactor is declining. As it operates as an interface between air and water, it causes a negative impact on these two vital resources. Currently, the pampa agriculture is simplified with a marked tendency towards spring-summer crops, where the main crops are RR soybean and corn. Herbicides are neither retained nor degraded in the soil, which results in polluted groundwater and surface waters. The objectives of this study were: a) to verify the presence of glyphosate and aminomethylphosphonic acid (AMPA) in Pergamino stream (a typical representative of the most productive agricultural region of Argentina) under different land use and to detect if in the detections there was a space-time pattern, and b) to verify the detection of these molecules in groundwater of the upper same basin under exclusively rural land use. Surface stream was sampling in six sites (five under rural land use and one under urban-industrial land use) at a rate of one sample by spring, summer and winter seasons (2010-2013, 54 total samples). Groundwater glyphosate and AMPA concentrations were determined in 24 piezometers constructed at two positions of the landscape, across the groundwater flow direction, sampled at two sampling dates (2010 and 2012, 45 total samples). In surface water, glyphosate and AMPA were detected in 54 and 69% of the samples analyzed, respectively. The median concentrations were 0.9 and 0.8 μg L-1 for glyphosate and AMPA and maximal concentrations 258 and 5865 μg L-1, respectively. The sampling site under urban-industrial land use had abnormally high concentrations of glyphosate in the spring (attributed to point pollution), a fact that not allowed to see differences in the remaining sampling times under different land uses. AMPA concentrations under urban-industrial land use were high and higher than rural land use in 3 studied seasons. Under rural land use, AMPA differences between seasons were found, being the highest concentration in spring (1.9 μg L-1). In groundwater glyphosate and AMPA concentrations were detected in 32 and 36% of the analyzed samples respectively. Medium and maximum glyphosate and AMPA concentrations were 0.7 and 1.0 μg L-1, and 2.3 and 6.0 μg L-1, respectively. In the first sampling date, glyphosate and AMPA were not detected probably associated with a dilution during a period of high groundwater recharge. On the contrary, in the second date the two molecules were detected in coincidence with a previous period with lowering water table accompanied by the first recharges. The temporal dynamics showed that herbicides are found in higher concentrations in surface water during the spring, and this is possibly associated with overlapping applications with rains that produce runoff. In groundwater, detections were associated with periods where the first small recharges are produced, which are concentrated in solutes. Loss of the environmental services retention and degradation of glyphosate of the agricultural soils was confirmed

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Assessing Groundwater Resources Sustainability Using Groundwater Footprint Concept

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Over-pumping, water table depletion and climate change impacts require effective groundwater management. The Groundwater Footprint (GWF), introduced by Gleeson et al. in 2012 expresses the area required to sustain groundwater use and groundwater dependent ecosystem services. GWF represents a water balance between aquifer inflows and outflows, focusing on environmental flow requirements. Developing the water balance, precipitation recharge and additional recharge from irrigation are considered as inflows, whereas outflows are considered the groundwater abstraction from the aquifer of interest and the quantity of groundwater that is needed to sustain ecosystem services. The parameters required for GWF calculation can be estimated through in-situ measurements, observations and models outputs. The actual groundwater abstraction is often difficult to be estimated with a high accuracy. Environmental flow requirements can be calculated through different approaches; the most accurate of which are considered the ones that focus on hydro-ecological data analysis.

As the GWF is a tool recently introduced in groundwater assessment and management, only a few studies have been reported in the literature to use it as groundwater monitoring and management tool. The present study emphasizes on a case study in Southern Europe, where awareness should be raised about rivers' environmental flow. GWF concept will be applied for the first time to a pilot area in Greece, where the flow of the perennial river that crosses the area of interest is dependent on baseflow. Recharge and abstraction of the pilot area are estimated based on historical data and previous reports and a groundwater flow model is developed using Visual Modflow so as to diminish the uncertainty of the input parameters through model calibration. The groundwater quantity that should be allocated on surface water body in order to sustain satisfactory biological conditions is estimated under the assumption that surface water and groundwater contribute to the environmental flow in an equally proportion as in case of natural flow. In order to express baseflow as a percentage of natural mean flow, a precipitation-runoff model is developed. The environmental flow of the river of interest is estimated as a percentage of the river's average flow (Tennant method). Subsequently, the groundwater contribution is calculated as a percentage of the environmental flow equal to the percentage of the baseflow in the natural flow. GWF is finally compared with the actual size of the area of interest in order to assess the groundwater use and sustainability of this area.

Assessing Groundwater Resources Sustainability Using Groundwater Footprint Concept

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1. INTRODUCTION

The Groundwater Footprint (GWF), introduced by Gleeson et al. in 2012, expresses the area required to sustain groundwater use and groundwater dependent ecosystem services. GWF represents **a water balance** between aquifer inflows and outflows, **focusing on environmental flow requirements**.

As the GWF is a tool recently introduced in groundwater assessment and management, only a few studies have been reported in the literature to use it as groundwater monitoring and management tool. The present study emphasizes on a case study in Southern Europe, where awareness should be raised about rivers' environmental flow. The GWF concept is applied for the first time to a pilot area in Greece, the Chania Valley, Crete.

2. CASE STUDY: THE CHANIA VALLEY

- Important agricultural area of Greece
- Over-pumping of groundwater resources
- Tavronitis and Keritis rivers are crossing the area
- Recharge through the springs of Agyia (karstic springs at the southern boundary of the pilot area)

Fig.1 - Hydrogeological Map of the Chania Valley

3. METHODOLOGY

- The **groundwater footprint (GWF)** is defined as:

$$GWF\ (m^2) = \frac{C\left(\frac{m}{d}\right)}{R\left(\frac{m}{d}\right) - E\left(\frac{m}{d}\right)} \cdot A(m^2)$$

where, C the annual outflows from the aquifer,

R the recharge rate,

E the groundwater contribution to environmental streamflow

A the areal extent of the aquifer of interest

- **Recharge and abstraction** of the pilot area are estimated based on historical data and previous reports and a groundwater flow model, developed using **Visual Modflow** in order to diminish the uncertainty of the input parameters through model calibration.

3. METHODOLOGY

- The **groundwater quantity that should be allocated on surface water bodies** in order to sustain satisfactory biological conditions is estimated under the assumption that **surface water and groundwater contribute equally both to the environmental flow and to the natural flow** (Sood et al., 2016).
- The Chania Valley GWF parameters estimation procedure is presented in Fig.2.

C
- is estimated through the developed groundwater flow model.
- refers to the total outflow of the aquifer (abstraction, outflows to the sea).

R
- is estimated through the developed groundwater flow model.
- refers to the total recharge of the aquifer (rainfall, recharge from water springs).

E
- is calculated as the same percentage of the baseflow in the natural flow.
- For baseflow estimation, a HEC-HMS (USACE) precipitation-runoff model is developed.
- The total environmental flow, concerning both groundwater and surface water contribution, is estimated based on Tennant method.

Fig.2 - Steps to GWF parameters estimation

4. RESULTS

The GWF in Chania Valley, Crete is estimated for the first time with respect to the groundwater contribution to achieve **a)** good and **b)** optimum environmental conditions.

- Based on Tennant method, the total environmental flow of the rivers crossing the Chania Valley is calculated as **a)** 30% of the mean average flow to ensure fair habitat conditions and as **b)** 60% of the mean average flow to ensure optimum environmental conditions.
- The groundwater flow simulation outputs are presented in Fig.3, at the end of the wet period in 2006.

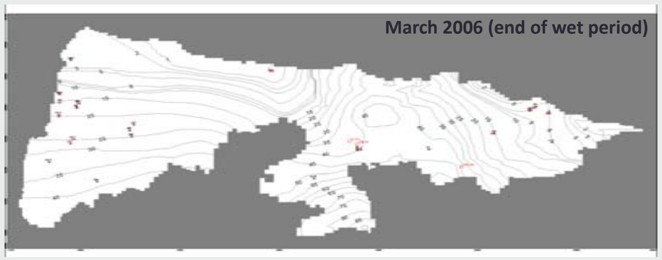

Fig.3 - Simulation of the Groundwater Flow System in Chania Valley

4. RESULTS

- The inflows and outflows of the aquifers are estimated through the water balance presented in Table 1.

INFLOW	Direct Recharge (precipitation)	Recharge (springs of Agyia)	River-Aquifer Interaction	Total Inflow
mcm/year	6,5	3,6	22,2	32,3
OUTFLOW	Pumping	Outflow to the Sea	River-Aquifer Interaction	Total Outflow
mcm/year	3,5	24,1	4,8	32,4

Table 1 - Water balance on pilot aquifer (Mean values, simulation period 2004-2008)

- **For good environmental conditions** (i.e. environmental flow equal to 30% of the mean flow), the GWF is estimated equal to 178,93Km^2, that means almost **89,4% of the actual area of the aquifer**.
- **For optimum environmental conditions**, the contribution of the groundwater to the environmental streamflow should be greater and in this case the GWF is estimated 187,69Km^2, about **93,8% of the actual area of the aquifer**.

5. CONCLUSIONS

- The GWF/A ratios computed in Chania Valley, which are lower than 1, indicate that the groundwater management in the area is sustainable.
- However, **the GWF is estimated for mean annual values, so it does not include the groundwater system response to the seasonal variability of abstraction and recharge.** In addition, **the variables used for GWF calculation are subject to uncertainty,** which should be taken into account.
- The GWF could be proved to be **a useful tool for groundwater analysis and policy** as it can raise awareness since it is intuitive to the general public. However, in order to develop the GWF method into a powerful tool, the method should be tested in changing conditions and the environmental flow requirements should be estimated with the most accurate method, based on expert consultation.

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Groundwater level prediction by Artificial Neural Network model in Eastern Jeju Island, Korea

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The size of rainfall In the Jeju Island (Republic of Korea) is largest in whole country. Due to the rapid recharge of deep aquifers through highly permeable volcanic basalt rock, most streams dry up shortly after rainfall events. For this reason, accurate estimation of hydrologic components is challenging even with conventional watershed hydrologic model. People in this island rely greatly upon the groundwater resources by pumping for agricultural water use. However, local government has to control the maximum use of agricultural groundwater especially in drought period to avoid groundwater depletion. To adapt this status the groundwater level prediction model is developed by using artificial neural network algorithm. The model uses rainfall and groundwater level data for training and calibration by back propagation and then predicts the groundwater level with predicted rainfall data sets made based on the various scenarios applying drought conditions. For the 10 groundwater stations in eastern area, we performed 6 months prediction successfully. These results can be used for monthly groundwater level prediction for severe drought period in this island.

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Classification management plan of groundwater quality in Taiwan

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Taiwan Environmental Protection Administration has been monitoring regional water quality for 14 years. Since the beginning of 2002 till now, there are 453 regional groundwater monitoring wells in ten groundwater subregions in Taiwan, and the monitoring of groundwater quality has been carried out for a long time. Currently, water quality monitoring project has reached 50 items, while the number of water quality monitoring data has reached more than 20,000. In order to use the monitoring data efficiently, this study constructed the localized groundwater quality indicators of Taiwan. This indicator takes into account the different users' point of view, incorporating the Taiwan groundwater pollution monitoring standards (Category II), irrigation water quality standard and drinking water source water quality standard. 50 items of water quality monitoring projects were simplified and classified. The groundwater quality parameters were divided into five items, such as potability for drinking water, salting, external influence, health influences and toxicity hazard. The weight of the five items of groundwater was calculated comprehensively, and the groundwater quality of each monitoring well was evaluated with three grades of good, ordinary, and poor. According to the monitoring results of the groundwater monitoring wells in October to December of 2016, about 70% of groundwater quality in Taiwan is in good to ordinary grades. The areas with poor groundwater quality were mostly distributed in coastal, agriculture and part of the urban areas. The conductivity or ammonia nitrogen concentration was higher in those regions, showing that groundwater may be salinized or affected by external influences. Groundwater quality indicators can clearly show the current comprehensive situation of the groundwater environment in Taiwan and can be used as a tool for groundwater quality classification management. The indicators can coordinate with the Taiwan land planning policy in the future, and will be able to effectively grasp the changes of the national sub-regional environmental resources, which can serve as one of the important references in national land zoning according to environmental resources.

Keywords: Groundwater Quality Indicators, Groundwater Quality Classification management

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An approach of groundwater management in Barcelona City

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Urban groundwater is a valuable resource since its quantity is larger than frequently expected due to additional recharge sources (Lerner, 2002; Vázquez-Suñé et al., 2003). Its interaction with the complex infrastructures network makes the water authorities a challenge to ensure a proper water management. Necessary datasets to ensure a suitable water management have normally different origins and formats. At the same time, the water management of a city involves different decision makers with different knowledges. In this scenario, it is a necessity to create a common environment where different actors would be able to understand and analyze problems in the same way. It should be also necessary to store, analyze and visualize all the required data in the same formats within its geographical context by using standardized specific tools. To apply these recommendations for the urban groundwater management of the Barcelona City Council, we have implemented a software platform developed in a Geographic Information System (GIS) environment. These GIS-based tools will give support to the users for storing, managing, and analyzing geological, hydrogeological and hydrochemical data in 2D and in a 3D context (Velasco et al., 2013). This implementation will improve the groundwater management in Barcelona city optimizing the analysis and decision making processes.

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A project on groundwater research inventory and classification to make groundwater visible

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Hydrogeology related research activities cover a wide spectrum of research areas at EU and national levels. The European knowledge base on this important topic is widespread and fragmented into broader programs generally related to waterresources, environment or ecology.

In order to achieve a comprehensive understanding on the groundwater theme, the KINDRA project (Knowledge Inventory for Hydrogeology Research - www.kindraproject.eu) seeks to carry out an accurate assessment of the state of the art in hydrogeology research and to create a critical mass for scientific knowledge exchange of hydrogeology research, to ensure wide accessibility and applicability of research results, including support of innovation and development, and to reduce unnecessary duplication of efforts.

The first two years of the project have focused its efforts in developing the concept of a Harmonized Terminology and Methodology for Classification and Reporting Hydrogeology related Research in Europe (HRCSYS) as well as its implementation in the European Inventory of Groundwater Research (EIGR).

For developing the common terminology, keywords characterizing research on groundwater have been identified from two main sources: the most important EU directives and policy documents and from groundwater related scientific literature. To assess the importance and pertinence of the keywords, these have been ranked by performing searches via the Web of Science, Scopus and Google Scholar search engines. The complete merged list of keywords consisting of more than 200 terms has been organized in a tree hierarchy, identifying three main categories: Societal Challenges (SC), Operational Actions (OA) and Research Topics (RT). The relationships among these main categories expressed by a 3D approach, identifying single intersections among 5 main overarching groups for each category.

The EIGR itself contains metadata (about 1800 records at the moment) of research efforts and topic related knowledge deliverables (scientific reports, articles, projects, etc.) illustrating and providing links to research efforts carried out through Europe since 2000, indicating where data can be retrieved, and following their classification according to the proposed methodology.

Both the HRC-SYS classification approach and the EIGR tool, are fundamental to achieve the main aim of the KINDRA project: to create an overview of the scientific knowledge covering European countries by means of an accurate assessment of hydrogeology research in various geographical and geo-environmental settings, and to allow for a direct comparison and exploit existing synergies.

The scope of the project also includes identification of future trends, critical challenges and research gaps, to improve management and policy development for groundwater resources on a EU level coherently with the Water Framework Directive (WFD) and Groundwater Directive (GWD). As part of the work to be carried out in 2017, the identified research gaps will be converted into specific recommendations for the further development of EU level policies and research programmes.

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An interdisciplinary approach for groundwater management in area contaminated by fluoride in East African Rift System

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Groundwater is the main source of fresh water supply for most of the rural communities in Africa (approximately 75% of Africans has confidence in groundwater as their major source of drinking water). Many African countries has affected by high fluoride concentration in groundwater (up to 90 mg/L), generating the contamination of waters, soils and food, in particular in the eastern part of the continent. It seems that fluoride concentration is linked to geology of the Rift Valley: geogenic occurrence of fluoride is often connected to supergenic enrichment due to the weathering of alkaline volcanic rocks, fumaric gases and presence of thermal waters.

The H2020 project FLOWERED (de-FLuoridation technologies for imprOving quality of WatEr and agRo-animal products along the East African Rift Valley in the context of aDaptation to climate change) wish to address environmental and health (human and animal) issues associated to the fluoride contamination in the African Rift Valley, in particular in three case study area located in Ethiopia, Tanzania and Kenya.

FLOWERED aims to develop an integrated, sustainable and participative water and agriculture management at a cross-boundary catchment scale through a strong interdisciplinary research approach. It implies knowledge of geology, hydrogeology, mineralogy, geochemistry, agronomy, crop and animal sciences, engineering, technological sciences, data management and software design, economics and communication.

The proposed approach is based on a detailed knowledge of the hydrogeological setting, with the identification and mapping of the specific geological conditions of water contamination and its relation with the different land uses. The East African Rift System (EARS) groundwater circulation and storage, today already poorly understood, is characterized by a complex arrangement of aquifers. It depends on the type of porosity and permeability created during and after the rock formation, and is strongly conditioned by the tectonic and volcanic processes. Data regarding geological and hydrogeological settings and the assessment of the vulnerability of groundwater bodies will constitute the necessary information for the implementation of a sustainable water management and for the proposal of sustainable and suitable strategies for water sanitation and agricultural system.

Taking into account the vulnerability of the aquifers and groundwater circulation, innovative agricultural practices will be assessed too, aiming to mitigate the impacts of fluoride contamination of water and soil on productivity of selected food and forage crops and dairy cattle health and production. Innovative defluoridation technologies for the sanitation of drinking water, which mainly operate at rural area scale, will be tested and implemented, aiming at providing a sustainable and safe water supply. Furthermore, the development of an innovative and shared Geo-data system for the knowledge management will support the implementation of an integrated, sustainable and participative water and agriculture management system. Moreover, supported by the Small and Medium-sized Enterprises (SMEs), a developed market analysis for the proposed defluoridation technologies accounting also for the social and environmental factors will be included in the project.

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Groundwater vulnerability maps for pesticides for Flanders

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Pesticides are increasingly being detected in shallow groundwater and and are one of the main causes of the poor chemical status of phreatic groundwater bodies in Flanders. There is a need for groundwater vulnerability maps in order to design monitoring strategies and land-use strategies for sensitive areas such as drinking water capture zones. This research focuses on the development of generic vulnerability maps for pesticides for Flanders and a tool to calculate substance-specific vulnerability maps at the scale of Flanders and at the local scale. (1) The generic vulnerability maps are constructed using an index based method in which maps of the main contributing factors in soil and saturated zone to high concentrations of pesticides in groundwater are classified and overlain. Different weights are assigned to the contributing factors according to the type of pesticide (low/high mobility, low/high persistence). Factors that are taken into account are the organic matter content and texture of soil, depth of the unsaturated zone, organic carbon and redox potential of the phreatic groundwater and thickness and conductivity of the phreatic layer. (2) Secondly a tool is developed that calculates substance-specific vulnerability maps for Flanders using a hybrid approach where a process-based leaching model GeoPEARL is combined with vulnerability indices that account for dilution in the phreatic layer. The GeoPEARL model is parameterized for Flanders in 1434 unique combinations of soil properties, climate and groundwater depth. Leaching is calculated for a 20 year period for each 50 x 50 m gridcell in Flanders. (3) At the local scale finally, a fully process-based approach is applied combining GeoPEARL leaching calculations and flowline calculations of pesticide transport in the saturated zone to define critical zones in the capture zone of a receptor such as a drinking water well or a river segment.
The three approaches are explained more in detail and illustrated with the results for the entire Flanders region and for a case-study focusing at a drinking water production site in West Flanders.

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Multi-scale approach for 3D hydrostratigraphic and groundwater flow modelling of Milan (Northern Italy) urban aquifers.

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During the last century, urban groundwater was heavily exploited for public and industrial supply. As the water demands of industry have fallen, many cities are now experiencing rising groundwater levels with consequent concerns about localized flooding of basements, reduction of soil bearing capacities under foundations, soil internal erosion and the mobilization of contaminants. The city of Milan (Northern Italy) draws water for domestic and industrial purposes from aquifers beneath the urban area. The rate of abstraction has been varying during the last century, depending upon the number of inhabitants and the development of industrial activities. The groundwater abstraction raised to a maximum of about 350x106 m3/yr in the middle 1970s and has successively decreased to a value of about 230x106 m3/yr at present days. This caused a water table raise at an average rate of about 1 m/yr inducing infiltrations and flooding of deep constructions (e.g. building foundations and basements, underground subway excavations).

Starting from a large hydrostratigraphic database (8628 borehole logs), a multi-scale approach for the reconstruction of the aquifers geometry (unconfined and semi-confined) at regional-scale has been used. First, a three-level hierarchical classification of the lithologies (lithofacies, hydrofacies, aquifer groups) has been adopted. Then, the interpretation of several 2D cross-sections was attained with Target for ArcGIS exploration software. The interpretation of cross-sections was based on the characteristics of depositional environments of the analysed aquifers (from meandering plain to proximal outwash deposits), on the position of quaternary deposits, and on the distribution of geochemical parameters (i.e. indicator contaminants and major ions). Finally, the aquifer boundary surfaces were interpolated with standard algorithms.

The hydraulic properties of analysed aquifers were estimated through the analyses of available step-drawdown tests (Theis with the superimposition solution) and use of empirical relationships from grain-size distribution data, respectively for semi-confined and unconfined aquifers.

Finally, 3D Finite Element groundwater flow models have been developed both at regional and local “metropolitan” scale. The regional model covers an area of 3,135.15 km2, while the local model comprises the Milan metropolitan area with an extension of 457 km2. Both models were discretized into a triangular finite element mesh with local refinement in proximity of pumping wells. The element size ranges from 350 to 30 meters and from 200 to 2 meters, respectively for regional and local model. The calibration was done by the comparison with the available water level data for different years (from 1994 to 2016). The calibrated permeability values are consistent with the estimated ones and the sensitivity analysis on hydraulic parameters suggests a minor influence of the aquiclude layer separating the two aquifers.

The challenge is to provide the basis for new types of applied outputs so that they may better inform strategic planning options, ground investigation, and abstraction strategies.

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Effects of climate change on groundwater: observed and forecasted trends on Italian systems

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Groundwater represents the main source of water supply at global level. In Italy, as well as in most European countries, water needs are mainly covered by groundwater exploitation. The reliance on this resource is continuously growing, given the key role that groundwater plays for mitigating the climate change/variability and for addressing the significant increase in the global water demand. Despite this, and unlike surface waters, groundwater bodies have not been widely studied, and there is a general paucity of quantitative information, especially in relation to climate change. Although groundwater systems are more resilient to climate change than surface waters, they are affected both directly and indirectly. The estimation of the entity of these effects is mandatory for a reliable management of this crucial resource.

The analysis of hydro-meteorological data over a few decades highlights that also the Italian territory is experiencing a change of the climate regime. Besides the increase of mean annual temperature, observed in particular since the early 1980s, longer and more frequent drought periods have been registered, as well as an increase of extreme events characterized by heavy rainfall. It is also noticeable a decrease in total rainfall, that is much more evident in the period from January to June. In addition to the reduced yearly inputs from precipitation, such trends determine also a lower snow accumulation and earlier snow melt in mountain areas, a general increase of evapotranspiration rates and an increased runoff fraction of the effective rainfall amount.

As flood hydrographs of several major Italian rivers (e.g., Po, Brenta and Arno rivers) confirm, evident effects concern surface water resources. The main observed phenomena consist in the decline of mean annual discharge, the increase of extreme events with high discharge concentrated in short periods, and longer and earlier periods of low base flow.

Impacts on groundwater recharge are not well understood. However, data analysis at specific Italian sites indicate that they are actually occurring. Here we discuss the results of the analysis of the data provided by a set of groundwater monitoring sites, not affected by artificial water extraction. Data refer to flowrates in spring and water levels from piezometers, and they are representative of different typologies of aquifers, such as karst, fractured and unconsolidated, located in mountain and foothills areas of central and northern Italy. Both flowrates and water levels indicate a decline of groundwater yields in these systems over the last two decades. This trend is much more evident when focusing on the periods of high level conditions (i.e. maximum effect of infiltrated water), thus demonstrating the reduction of recharge. The more attenuated trend observed by analyzing low level periods (i.e. at the end of dry periods) testifies the buffer role of aquifers, which partially compensate the general reduction by releasing water from storage reserves. A tendency to consume more recharge water through sudden and short flow rate peaks is also observed for karst systems, as a consequence of the increased occurrence of storm events.

Furthermore, data were elaborated in order to study possible empirical relationships between meteorological parameters and groundwater quantity indices, in the wider framework of a research concerning the estimation of the performance of groundwater systems under specific climate scenarios.

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Groundwater quality across scales: impact on nutrient transport to large water bodies

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High concentrations of dissolved nutrients such as nitrogen (N) and phosphorus (P) in groundwater are an increasing concern in many areas of the world. Especially regions with high agriculture impact see widespread declining groundwater quality, with considerable uncertainty mainly regarding the impact of phosphorus (P). Implications reach from direct impacts on different water users to discharge of nutrient-rich groundwater to rivers, lakes and coastal areas, where it can contribute to eutrophication, hypoxia or harmful algal blooms. While local-scale studies are abundant and management options exist, quantitative approaches at regional to continental scales are scarce and frequently have to deal with data inconsistencies or are temporally sparse. Here, we present the research framework to combine large databases of local groundwater quality to data sets of climatical, hydrological, geological or landuse parameters. Pooling of such information, together with robust methods such as water balances and groundwater models, can provide constraints such as upper boundaries and likely ranges of nutrient composition in various settings, or for the nutrient transport to large water bodies. Remote Sensing can provide spatial information on the location of groundwater seepage. Results will eventually help to identify focus areas and lead to improved understanding of the role of groundwater in the context of global biogeochemical cycles.

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Characterization of Surface Water and Groundwater Quality in the Lower Tano River Basin Using Statistical and Isotopic Approach.

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This research is part of a PhD research work "Hydrogeological Assessment of the Lower Tano river basin for sustainable economic usage, Ghana, West - Africa". In this study, the researcher investigated surface water and groundwater quality in the Lower Tano river basin. This assessment was based on some selected sampling sites associated with mining activities, and the development of oil and gas. Statistical approach was applied to characterize the quality of surface water and groundwater. Also, water stable isotopes, which is a natural tracer of the hydrological cycle was used to investigate the origin of groundwater recharge in the basin. The study revealed that Pb and Ni values of the surface water and groundwater samples exceeded the WHO standards for drinking water. In addition, water quality index (WQI), based on physicochemical parameters(EC, TDS, pH) and major ions(Ca^{2+}, Na^{+}, Mg^{2+}, HCO_3^-,NO_3^-, CL^-, SO_4^{2-}, K^+) exhibited good quality water for 60% of the sampled surface water and groundwater. Other statistical techniques, such as Heavy metal pollution index (HPI), degree of contamination (Cd), and heavy metal evaluation index (HEI), based on trace element parameters in the water samples, reveal that 90% of the surface water and groundwater samples belong to high level of pollution. Principal component analysis (PCA) also suggests that the water quality in the basin is likely affected by rock – water interaction and anthropogenic activities (sea water intrusion). This was confirm by further statistical analysis (cluster analysis and correlation matrix) of the water quality parameters. Spatial distribution of water quality parameters, trace elements and the results obtained from the statistical analysis was determined by geographical information system (GIS). In addition, the isotopic analysis of the sampled surface water and groundwater revealed that most of the surface water and groundwater were of meteoric origin with little or no isotopic variations. It is expected that outcomes of this research will form a baseline for making appropriate decision on water quality management by decision makers in the Lower Tano river Basin.

Keywords: Water stable isotopes, Trace elements, Multivariate statistics, Evaluation indices, Lower Tano river basin.

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Effects of human water management on California drought risk

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Contribution of human water management to the intensification or mitigation of hydrological drought over California is investigated using the PCR-GLOBWB hydrological model at 0.5° resolution for the period 1979-2014. We demonstrate that including water management in the modeling framework results in more accurate discharge representation. During the severe 2014 drought, water management alleviated the drought deficit by ∼50% in Southern California through reservoir operation during low flow periods. However, human water consumption (mostly irrigation) in the Central Valley increased drought duration and deficit by 50% and 50-100%, respectively. Return level analysis indicates that there is more than 50% chance that the probability of occurrence of an extreme 2014-magnitude drought event was at least doubled under the influence of human activities compared to natural variability. This impact is most significant over the San Joaquin Drainage basin with a 50% and 75% likelihood that the return period is more than 3.5 and 1.5 times larger, respectively, because of the human impact on drought. A detailed study of the relative attribution of different types of human activities (e.g., groundwater pumping, reservoir operation and irrigation) on changes in drought risk over California is conducted through a higher 10 km resolution simulation. This hydrological modeling, attribution and risk assessment framework is further extended to other drought-prone areas and major drought events in the contiguous U.S., including the 2006/2007 southeastern U.S. drought, the 2011 Texas-northern Mexico drought over the southern plains and the 2012 drought over the central Great Plains.

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Groundwater vulnerability assessment and validation on the example of Gömör-Torna Karst, Hungary and Slovakia

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A comprehensive resource and source groundwater vulnerability assessment was carried out on a transboundary test site of the Gömör-Torna Karst (Hungary and Slovakia). The main goal of the investigation was to understand and map vulnerability in a more general hydrogeological context, taking into consideration the special characteristics of gravity-driven groundwater flow systems, i.e. the flow dynamics in the area.
In order to assess vulnerability, parametric, semi-quantitative approaches were adapted, applied, compared and validated on the test area. Focusing on the usual "weak points" of the assessment (as crucial but nonetheless mainly just roughly estimated parameters), complementary investigations were carried out with diverse techniques. The characteristic clayey sediment cover may have major impact on the infiltration. Its spatial extension and role in the infiltration process were investigated by means of geophysical techniques and grain-size measurements. In order to understand the flow dynamics in the saturated zone better, results of tracer tests were analyzed. Besides that, spring hydrograph and recession curve analysis were carried out based on long-term daily spring discharge data series.
The study provides an approach in order to improve the reliability of vulnerability maps. The well-studied and intensively karstified area of the Gömör-Torna Karst serves also as an appropriate example for further similar studies to find the best possible investigation and mapping strategies and thus to create comprehensive, reliable, process-based vulnerability maps.
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Geochemical processes controlling the fluoride concentrations in the groundwater of the Lake Acıgöl Basin (Denizli, Turkey)

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The lacustrine Acıgöl basin formed as an extensional half-graben host to various bodies of water, such as cold-hot springs, lakes, streams, and wells. This study examines the fluoride evolution of the groundwater in the semi-arid, closed Acıgöl Basin (using 165 samples). The economically important saline/hyper-saline lake that borders the NE-trending Acıgöl fault zone is located in the southern part of the basin. The brackish springs and deep waters that discharge along the NE-trending Acıgöl fault zone feed the hyper-saline lake. The groundwater chemistry of springs that discharge near or around the lake is affected by carbonate- and sulphate-rich lacustrine sediments.

The fluoride concentrations varied from 0 to 2.9 mg/L (mean value 0.8 mg/L, n=165) in groundwater samples of the Lake Acıgöl Basin . The mean fluoride concentration values were 0.5 mg/L (n=42) in dry seasons and 0.9 mg/L (n=123) in wet seasons. According to the water type, the mean value of fluoride concentrations in deep wells, shallow wells, springs, and streams were 0.8 mg/L, 0.3 mg/L, 0.9 mg/L, and 0.2 mg/L, respectively. Over 12.7 % of the groundwater in basin had fluoride concentrations above 1.5 mg/L (the WHO drinking guideline), and 38% of the groundwater in the basin had fluoride concentrations above 1.0 mg/L (Turkish Standards-TS266). The highest fluoride concentrations were measured in brackish deep groundwater (2.9 mg/L) that bordered the hyper-saline lake and Beylerli Thermal springs (2.7 mg/L) located south west of the hyper-saline lake. The Hayriye Başpınar Spring had the lowest fluoride concentration. The high-fluoride groundwater zones were mainly located along the NE-trending Acıgöl fault zone at the south part of the basin. The mean fluoride concentration value was 1 mg/L at these zones.

The fluoride enrichment in springs discharged from the Acıgöl fault zone is higher than in springs discharged from lithological units. According to the spatial variation map of fluoride, the main fluoride source in the basin is the thermal waters around Beylerli. The groundwater flow direction of the west part of the basin is from Beylerli to the hyper-saline lake. The fluoride concentration decreases from Beylerli to the hyper-saline lake in the direction of groundwater flow.

The fluoride concentration in the springs and deep waters discharged along the Acıgöl fault zone was positively correlated with that of Ec, Na, Cl-, and SO4-2. These correlations indicate that groundwater with high Cl- and SO4-2 contents help dissolve some fluoride-rich minerals and evaporates, such as gypsum and mirabilite. Dissolving evaporates in lacustrine sediments bound to the Acıgöl fault by springs increases fluoride concentrations. The water type of groundwater contaion high fluoride is Na-SO4, Na-Cl, Ca-SO4 ve Mg-SO4. The interactions between groundwater and fluoride-rich minerals may be responsible for the increased fluoride concentration in groundwater discharged from lithological units. The Karaböğürtlen Formation in the southern part of the Acıgöl Basin contains fluoride-rich minerals, such as fluorapatite and hornblende.

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Nitrate Contamination in the groundwater of the Lake Acıgöl Basin, SW Turkey

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The lacustrine Acıgöl basin, formed as an extensional half-graben, hosts various bodies of water, such as cold-hot springs, lakes, streams, and wells. The hydrologically closed basin contains a hypersaline lake (Lake Acıgöl) located in the southern part of the basin. The brackish springs and deep waters discharged along the Acıgöl fault zone in the southern part of the basin feed the hypersaline lake. Groundwater is used as drinking, irrigation, and domestic water in the closed Acıgöl Basin. Groundwater flows into the hypersaline lake from the highland. The Acıgöl basin hosts large plains (Hambat, Başmakçı, and Evciler). Waters in agricultural areas contain high amounts of nitrate; groundwater samples in agricultural areas contain nitrate levels higher than 10 mg/L. Nitrate concentrations in the groundwater samples varied from 0 to 487 mg/L (n=165); 25.4 % of the groundwater samples from the basin had nitrate concentrations above 10 mg/L (the WHO drinking guideline) and 52.2% of the groundwater samples from the basin had nitrate concentrations above 3.0 mg/L, and these high values were regarded as the result of human activity. The highest nitrate values were measured in the Hambat plain (480 and 100 mg/L) and Yirce Pinari spring (447 mg/L), which discharges along the Acıgöl fault zone in the southern part of the basin. The average multi-temporal nitrate concentration of the Yirce Pınarı spring was 3.3 mg/L. Extreme nitrate values were measured in the Yirce Pınarı spring during periods when sheep wool was washed (human activity).

The lowest nitrate concentrations were observed in some springs that discharged along the Acıgöl fault zone in the southern part of the basin. Nitrate was not detected in deep groundwater discharged along the Acıgöl fault zone. Nitrate concentrations in deep groundwater and some springs discharged along the Acıgöl fault zone and those feeding the hypersaline lake were significantly affected by redox conditions. Nitrate in these reducing waters was transformed into ammonium. Nitrate concentrations in the Acıgöl Basin were enriched in groundwater beneath agricultural areas and this affected redox conditions. The main source of nitrate contamination was agricultural fertilizers. Elevated nitrate concentrations in groundwater, especially in agricultural areas of the Acigol Basin, can cause public health problems and environmental pollution.

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Groundwater nitrate pollution: High-resolution approach of calculating the nitrogen balance surplus for Germany

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The latest inventory of the EU Water Framework Directive determined that 26.3% of Germany's groundwater bodies are in a poor chemical state regarding nitrate. As of late October 2016, the European Commission has filed a lawsuit against Germany for not taking appropriate measures against high nitrate levels in water bodies and thus failing to comply with the EU Nitrate Directive. Due to over-fertilization and high-density animal production, Agriculture was identified as the main source of nitrate pollution.
One way to characterize the potential impact of reactive nitrogen on water bodies is the soil surface nitrogen balance where all agricultural nitrogen inputs within an area are contrasted with the output, i.e. the harvest. The surplus nitrogen (given in kg N per ha arable land and year) can potentially leach into the groundwater and thus can be used as a risk indicator.
In order to develop and advocate appropriate measures to mitigate the agricultural nitrogen surplus with spatial precision, high-resolution data for the nitrogen surplus is needed. In Germany, not all nitrogen input data is available with the required spatial resolution, especially the use of mineral fertilizers is only given statewide. Therefore, some elements of the nitrogen balance need to be estimated based on agricultural statistics. Hitherto, statistics from the Federal Statistical Office and the statistical offices of the 16 federal states of Germany were used to calculate the soil surface balance annually for the spatial resolution of the 402 districts of Germany (mean size 890 km^2).
In contrast, this study presents an approach to estimate the nitrogen surplus at a much higher spatial resolution by using the comprehensive Agricultural census data collected in 2010 providing data for 326000 agricultural holdings. This resulted in a nitrogen surplus map with a 5 km x 5 km grid which was subsequently used to calculate the nitrogen concentration of percolation water. This provides a considerably more detailed insight on regions where the groundwater is particularly vulnerable to nitrate pollution and appropriate measures are most needed.

Geophysical Research Abstracts
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Application of artificial neural network model for groundwater level forecasting in a river island with artificial influencing factors

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Groundwater use has been increased for various purposes like agriculture, industry or drinking water in recent years, the issue related to sustainability on the groundwater use also has been raised. Accordingly, forecasting the groundwater level is of great importance for planning sustainable use of groundwater. In a small island surrounded by the Han River, South Korea, seasonal fluctuation of the groundwater level is characterized by multiple factors such as recharge/discharge event of the Paldang dam, Water Curtain Cultivation (WCC) during the winter season, operation of Groundwater Heat Pump System (GWHP). For a period when the dam operation is only occurred in the study area, a prediction of the groundwater level can be easily achieved by a simple cross-correlation model. However, for a period when the WCC and the GWHP systems are working together, the groundwater level prediction is challenging due to its unpredictable operation of the two systems. This study performed Artificial Neural Network (ANN) model to forecast the groundwater level in the river area reflecting the various predictable/unpredictable factors. For constructing the ANN models, two monitoring wells, YSN1 and YSO8, which are located near the injection and abstraction wells for the GWHP system were selected, respectively. By training with the groundwater level data measured in January 2015 to August 2015, response of groundwater level by each of the surface water level, the WCC and the GWHP system were evaluated. Consequentially, groundwater levels in December 2015 to March 2016 were predicted by ANN models, providing optimal fits in comparison to the observed water levels. This study suggests that the ANN model is a useful tool to forecast the groundwater level in terms of the management of groundwater.

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Groundwater quality in an abandoned metal extraction site: the case study of Campello Monti (NW Italy)

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Extractive activities present threat to natural water systems and their effects are observed even after the cessation of activities. The harmful effects of extractive activities such as deterioration of water sources by low quality waters or by allowing leaching of metals into groundwater makes it necessary to carry out careful, scientific and comprehensive studies on this subject. Consequently, the same problem statement was chosen as part of a PhD research Project. The PhD research is part of REMEDIATE project (A Marie Sklodowska-Curie Action Initial Training Network for Improved decision making in contaminated land site investigation and risk assessment, Grant Agreement No. 643087). The current work thus points out on the contamination of groundwater sources due to past mining activities in the area. Contaminated groundwater may act as possible contamination source to surface water also.

The impacts on water systems connected to mining activities depend on the ore type, metal being extracted, exploitation method, ore processing, pollution control efforts, geochemical and hydrogeochemical conditions of water and surroundings. To evaluate the effects posed by past metal extracting activities the study was carried out at an abandoned site used for extracting nickel in Campello Monti (Valstrona municipality, Piedmont region, Italy).

Campello Monti is located in basement of Southern Italian Alps in the Ivrea Verbano Zone. The area is composed of mafic rocks intruded by mantle periodite. The mafic formation consists of peridotites, pyroxenites, gabbros, anorthosites, gabbro-norite, gabbro-diorite and diorite. Mines were used for nickel exploitation from 9th Century and continued until 1940s. The long history of nickel extraction has left the waste contaminated with Ni and Co in the mountains alongwith tunnels used for carrying out metal extracting activities. The area around the site is used for housing, shows the presence of domestic animals and has Strona creek passing through it. The groundwater circulation takes place in fractured rocks, in waste dumps and tunnels used for extracting metal. Thus the abandoned site may contaminate local water sources.

To study the impacts on local water sources, water sampling and analysis were performed. Three sampling campaigns in June, July and October 2016 resulted in 16 groundwater samples (4 tap water samples, 3 samples from tunnels and 9 from springs) and 6 surface water samples. The samples were analyzed to measure alkalinity, electrolytic conductivity, pH , temperature, metals such as- Hg, Tl, Cd, Cr (total), Cr (VI), Ag, As ,Pb , Se, Ni, Co, Mn, Al, Fe, Cu, Zn, B and metal ions –CN-, Fl-, Mg2+, Na+, SO42-, NO_3- ,Cl-.

The water samples collected from tunnels showed nickel concentration ranging from 31.9 μg/ l to as high as 304 μg/ l (permissible limit for Ni in Italy according to DLgs. 152/06 is 20 μg/l). These groundwaters, being in close association with minerals containing heavy metals tend to dissolve such elements. The springs in mountains also contained Ni higher than 20 μg/l. These all groundwater systems act as source to Strona creek which showed Ni concentration of 512 μg/l.

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Dynamics of trace elements in shallow groundwater of an agricultural land in the northeast of Mexico

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The citrus zone located in northeastern Mexico covers an area of 8000 km2 and produces 10% of the Mexican citrus production. The aquifer system of this zone constitutes the major source of water for drinking and irrigation purposes for local population and provides base flows to surface water supplied to the city of Monterrey ([U+F07E] 4.5 million inhabitants). Although the study area is near the recharge zones, several works have reported nitrate pollution in shallow groundwater of this agricultural area, mainly due to animal manure and human waste produced by infiltration of urban sewers and septic tanks. Thus, the goals of this work were to assess the dynamics of selected trace elements in this aquifer system and determine if the trace element content in groundwater poses a threat to the population living in the area. Thirty-nine shallow water wells were sampled in 2010. These water samples were filtered through 0,45 μm pore size membranes and preserved with nitric acid for storage. The concentrations of Cd, Cs, Cu, Mo, Pb, Rb, Si, Ti, U, Y, and Zn were measured by ICP-MS. Also, sulfate concentrations were measured by ion chromatography in unacidified samples. Principal Component Analysis (PCA) performed in the data set show five principal components (PC). PC1 includes elements derived from silicate weathering, such as Si and Ti. The relationship found between Mo and U with sulfates in PC2 indicates that both elements show a high mobility in groundwater. Indeed, the concentrations of sulfate, Mo and U are increased as groundwater moves eastward. PC3 includes the alkali trace elements (Rb and Cs), indicating that both elements could be derived from the same source of origin. PC4 represents the heavy trace elements (Cd and Pb) whereas PC5 includes divalent trace elements such as Zn and Cu. None of the water samples showed trace element concentrations higher than the guideline values for drinking water proposed by the World Health Organization, which indicates that the analyzed trace elements in groundwater do not pose any significant threat to the population living in this area.

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Improved water resource management using three dimensional groundwater modelling for a highly complex environmental

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Proper allocation and management of groundwater is an important and critical challenge under rising water demands of various environmental sectors but good groundwater quality is often limited because of urbanization and contamination of aquifers. Given the predictive capability of groundwater models, they are often the only viable means of providing input to water management decisions. However, modelling flow and transport processes can be difficult due to their unknown subsurface heterogeneity and typically unknown distribution of contaminants. As a result water resource management tasks are based on uncertain assumption on contaminants patterns and this uncertainty is typically not incorporated into the assessment of risks associated with different proposed management scenarios.

A three-dimensional groundwater model was used to improve water resource management for a study area, where drinking water production is close to different former landfills and industrial areas. To avoid drinking water contamination, artificial groundwater recharge with surface water into the gravel aquifer is used to create a hydraulic barrier between contaminated sites and drinking water extraction wells. The model was used for simulating existing and proposed water management strategies as a tool to ensure the utmost security for drinking water. A systematic evaluation of the flow direction and magnitude between existing observation points using a newly developed three point estimation method for a large amount of scenarios was carried out. Due to the numerous observation points 32 triangles (three-points) were created which cover the entire area around the Hardwald. We demonstrated that systematically applying our developed methodology helps to identify important locations which are sensitive to changing boundary conditions and where additional protection is required without highly computational demanding transport modelling. The presented integrated approach using the flow direction between observation points can be easily transferred to a variety of hydrological settings to evaluate systematically groundwater modelling scenarios.

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Investigating climate change and groundwater related causes for eutrophication in Lake Lugano

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The groundwater-surface water interaction of the Lugano lake and the major aquifers within its watershed may be a factor in the total phosphorous load reaching the lake, which is responsible for its increasing eutrophication. Climate change has affected the surface water flows to the lake and surface water- groundwater interaction, thus affecting phosphorus load to the lake. Using the FREEWAT GIS environment, a groundwater flow model was constructed to simulate groundwater-surface water interaction for 5 main porous aquifers intersected by the Lugano Lake. The model simulates the groundwater flow in the porous aquifers, connecting all aquifers through the water level in the lake, as well as the changing surface water flows. Aim of the case study is twofold: firstly to exemplify the participatory approach by including stakeholders in all parts of the process rather than just in the discussion of the results and to focus the case study on areas of interest for all involved stakeholders, particularly climate change and increased eutrophication. Secondly the case study demonstrates the two portions of the FREEWAT environment developed by SUPSI-IST, the Observation Analysis Tool (OAT) and the Lake package. The OAT tool is used to incorporate several online climate and hydrological monitoring stations already existing around the Lugano watershed into the case study model, while the lake package will be used to simulate the interaction between the aquifers and the lake.The model delivers groundwater elevation levels and flow directions for all of the aquifers in relation to time, as well as volumetric budgets of ground and surface water, as well as sources and sinks thereof.

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Modelling the distribution of tritium in groundwater across South Africa to assess the vulnerability and sustainability of groundwater resources in response to climate change

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Groundwater is critical for sustaining human populations, especially in semi-arid to arid areas, where surface water availability is low. Shallow groundwater is usually abstracted for this purpose because it is the easiest to access and assumed to be renewable and regularly recharged by precipitation. Renewable, regularly recharged groundwater is also called modern groundwater, ie groundwater that has recently been in contact with the atmosphere. Tritium can be used to determine whether or not a groundwater resource is modern because the half-life of tritium is only 12.36 years and tritium is dominantly produced in the upper atmosphere and not in the rock mass. For this reason, groundwater with detectable tritium activities likely has a residence age of less than 50 years. In this study, tritium activities in 277 boreholes distributed across South Africa were used to develop a national model for tritium activity in groundwater in order to establish the extent of modern groundwater across South Africa. The tritium model was combined with modelled depth to water using 3079 measured static water levels obtained from the National Groundwater Archive and validated against a separate set of 40 tritium activities along the west coast of South Africa. The model showed good agreement with the distribution of rainfall which has been previously documented across the globe (Gleeson et al., 2015), although the arid Karoo basin in south west South Africa shows higher than expected tritium levels given the very low regional precipitation levels. To assess the vulnerability of groundwater to degradation in quality and quantity, the tritium model was incorporated into a multi-criteria evaluation (MCE) model which incorporated other indicators of groundwater stress including mean annual precipitation, mean annual surface temperature, electrical conductivity (as a proxy for groundwater salinization), potential evaporation, population density and cultivated land usage. The MCE model was then forward projected using predicted climate change from the ECHAM5/MPI-OM model for SRES high emission scenario A2. The resultant groundwater vulnerability map for South Africa indicates that groundwater across large parts of western South Africa, particularly along the west coast and Northern Cape regions, is extremely vulnerable to deterioration in both quality and quantity and this deterioration is most strongly linked to mean annual precipitation and potential evaporation. Accordingly, the west coast region of South Africa is now, and will remain in the future, the most vulnerable region to climate change in South Africa. Further investigation of the predicted evolution of climate, biodiversity and agricultural capacity in this region will be critical for developing sustainable groundwater management protocols.

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Groundwater resources vulnerability due to melting glaciers in the Talgar alluvian fan, northern Tien-Shan

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Alluvial fans on the mountain slopes in Central Asia are an important source of the groundwater, due to there capacity of storing large quantities of the fresh groundwater and due to the fact that most urban centres are situated in the mountainous terrain or along mountain slopes. The groundwater resources in the alluvial fans are replenished by the infiltration from the rivers, which drain the mountain catchments and by infiltration from the precipitation, and released on there lower reaches as a series of seasonal springs or infiltrated into the lower lying aquifers. The rivers with there catchments in the mountainous terrain are fed by the precipitation (with the peak in May-June due to snow melt) and glacier melt. The glacier meltwater constitutes up to 90% of the river runoff in July-August, due to peak in glacier melt and low precipitation, providing much needed freshwater for agriculture in the dry season.

In this study an attempt to quantify the importance of the glacier meltwater on the groundwater resources through groundwater modelling in the Talgar alluvial fan, Ili-Alatau mountain range has been performed.

The results suggest that glacier meltwater is a substantial portion of the groundwater resources in the Talgar alluvial fan, with up to 30m drop of the groundwater level, if the glaciers disappear, endangering existing groundwater supply. The transient simulations suggest that disappearance of the glaciers and highly variable annual precipitation would result in highly fluctuating groundwater levels, as well as disappearance of most of the springs at the foot of the alluvial fan. These results are especially relevant for the northern Tien-Shan, where glaciers have been rapidly retreating over last 50 years, and some of the glaciers could disappear in next decades.

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Groundwater vulnerability to drought in agricultural watersheds, S. Korea

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Drought can be generally defined by a considerable decrease in water availability due to a deficit in precipitation during a significant period over a large area. In South Korea, the severe drought occurred over late spring to early summer during from 2012 to 2015. In this period, precipitation decreased up to 10-40% compared with a normal one, resulting in reduction of stream flow and reservoir water over the country. It led to a shortage of irrigation water that caused great damage to grow rice plants on early stage. Furthermore, drought resulted in a negative effect on groundwater system with decline of its level. Change of the levels significantly reflects intrinsic characteristics of aquifer system. Identifying drought effects on groundwater system is very difficult because change of groundwater level after hydrological events tends to be delayed.
Therefore, quantitative assessment on decline of groundwater level in agricultural watersheds plays an essential role to make customized policies for water shortage since groundwater system is directly affected by drought. Furthermore, it is common to analyze the time-series groundwater data from monitoring wells including hydrogeological characteristics in company with meteorological data because drought effects on groundwater system is site-specific.
Currently, a total of 364 groundwater monitoring wells including 210 wells for rural groundwater management network(RGMN) and 154 wells for seawater intrusion monitoring network (SIMN) have been operating in agricultural watersheds in S. Korea. To estimate the effect of drought on groundwater system, monthly mean groundwater level data were obtained from RGMN and SIMN during the periods of 2012 to 2015. These data were compared to their past data in company with rainfall data obtained from adjacent weather stations.
In 2012 and 2014, mean groundwater level data in the northern part of the country during irrigation season(April to June), when precipitation was recorded to 10% and 30% of an average one during the past 30 years, decreased up to 1.32 m and 0.71 m compared to that of the normal year, respectively. In 2015, mean groundwater level in the same area with 40% of a normal precipitation decreased up to 0.51-0.77 m.
Consequently, total amounts of groundwater in aquifer have decreased due to the effect of periodic drought events during irrigation season. Effective policies should be required to manage groundwater vulnerability by drought in rural areas, South Korea.

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The impact of surface water - groundwater interactions on nitrate cycling assessed by means of hydrogeologic and isotopic techniques in the Alento river basin (Italy)

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Currently a major concern of water resources managers is to understand the fate and dynamics of nutrients in riverine ecosystems because of their potential impacts on both river quality and human health (e.g., European Council Directive 91/676/EEC). Nutrients are released within a catchment (or river basin) mainly by agricultural practices and urban/industrial activities, in addition to natural sources such as soils and organic matter. They are discharged into surface water bodies by means of nutrient-rich groundwater inflows and/or overland flow pathways, which can be important controls on hot moment/hot spot type biogeochemical behaviors. Groundwater has been recognized to have a major role in controlling stream ecosystem health since it influences stream ecology when surface and subsurface water are hydraulically connected. In particular, processes occurring at the reach or sub-reach scale more directly influence nutrient transport to rivers than larger scale processes.

In this general context, the main scope of this study, within the framework of the IAEA Coordinated Research Project (CRP) "Environmental Isotopes and Age Dating Methods to Assess Nitrogen Pollution and Other Quality Issues in Rivers", was to spatially and temporally quantify groundwater inflows to the Alento river (Southern Italy) to characterize sw-gw interactions in the catchment in order to finally assess nitrates contamination of a groundwater dependent river ecosystem.

Four sampling campaigns have been carried out in July and October 2014, in April 2015 and in June 2016 during which 1 spring, rain water, 17 surface water and 27 groundwater points were sampled all over the plain. The piezometric reconstruction has been realized by means of the monitoring of groundwater levels in 43 domestic and agricultural wells (10-15 m deep).

The preliminary hydrogeological (water table morphology and stream discharge measurements), physico-chemical (T and EC), hydrochemical and isotopic (222Rn, δD and δ18O) data evidence a gaining river in the northern part of the plain. Moreover, δD and δ18O data evidence a fast recharge from seasonal precipitations originating from evaporated and re-evaporated air masses. Finally, even though chemical data evidence no groundwater nitrate pollution (< 50 mg L-1) in the study area, δ15N and δ18O of dissolved nitrates have been used to infer possible nitrate sources in the study area.

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Vulnerability assessment of groundwater-dependent ecosystems based on integrated groundwater flow modell construction

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Groundwater-dependent ecosystems (GDEs) are highly influenced by the amount of groundwater, seasonal variation of precipitation and consequent water table fluctuation and also the anthropogenic activities. They can be regarded as natural surface manifestations of the flowing groundwater. The preservation of environment and biodiversity of these GDEs is an important issue worldwide, however, the water management policy and action plan could not be constructed in absense of proper hydrogeological knowledge. The concept of gravity-driven regional groundwater flow could aid the understanding of flow pattern and interpretation of environmental processes and conditions.

Unless the required well data are available, the geological–hydrogeological numerical model of the study area cannot be constructed based only on borehole information. In this case, spatially continuous geophysical data can support groundwater flow model building: systematically combined geophysical methods can provide model input. Integration of lithostratigraphic, electrostratigraphic and hydrostratigraphic information could aid groundwater flow model construction: hydrostratigraphic units and their hydraulic behaviour, boundaries and geometry can be obtained. Groundwater-related natural manifestations, such as GDEs, can be explained with the help of the revealed flow pattern and field mapping of features.

Integrated groundwater flow model construction for assessing the vulnerability of GDEs was presented via the case study of the geologically complex area of Tihany Peninsula, Hungary, with the aims of understanding the background and occurrence of groundwater-related environmental phenomena, surface water–groundwater interaction, and revealing the potential effect of anthropogenic activity and climate change. In spite of its important and protected status, fluid flow model of the area, which could support water management and natural protection policy, had not been constructed previously.

The 3D groundwater flow model, which was based on the scarce geologic information and the electromagnetic geophysical results, could answer the subsurface hydraulic connection between GDEs. Moreover, the gravity-driven regional groundwater flow concept could help to interpret the hydraulically nested flow systems (local and intermediate). Validation of numerical simulation by natural surface conditions and phenomena was performed. Consequently, the position of wetlands, their vegetation type, discharge features and induced landslides were explained as environmental imprints of groundwater.

Anthropogenic activities and climate change have great impact on groundwater. Since the GDEs are fed by local flow systems, the impact of climate change and anthropogenic activities could be notable, therefore the highly vulnerable wetlands have to be in focus of water management and natural conservation policy.

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Current and future groundwater recharge in West Africa as estimated from a range of coupled climate model outputs

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This research addresses the terrestrial water balance for West Africa. Emphasis is on the prediction of groundwater recharge and how this may change in the future, which has relevance to the management of surface and groundwater resources. The study was conducted as part of the BRAVE research project, “Building understanding of climate variability into planning of groundwater supplies from low storage aquifers in Africa – Second Phase”, funded under the NERC/DFID/ESRC Programme, Unlocking the Potential of Groundwater for the Poor (UPGro).

We used model output data of water balance components (precipitation, surface and subsurface run-off, evapotranspiration and soil moisture content) from ERA-Interim/ERA-LAND reanalysis, CMIP5, and high resolution model runs with HadGEM3 (UPSCALE; Mizielinski et al., 2014), for current and future time-periods.

Water balance components varied widely between the different models; variation was particularly large for sub-surface runoff (defined as drainage from the bottom-most soil layer of each model). In-situ data for groundwater recharge obtained from the peer-reviewed literature were compared with the model outputs.

Separate off-line model sensitivity studies with key land surface models were performed to gain understanding of the reasons behind the model differences. These analyses were centered on vegetation, and soil hydraulic parameters. The modelled current and future recharge time series that had the greatest degree of confidence were used to examine the spatiotemporal variability in groundwater storage. Finally, the implications for water supply planning were assessed.

Mizielinski, M.S. et al., 2014. High-resolution global climate modelling: the UPSCALE project, a large-simulation campaign. Geoscientific Model Development, 7(4), pp.1629–1640.

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A nationwide classification of New Zealand aquifer properties

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Groundwater plays an essential role in water provision for domestic, industrial and agricultural use. Groundwater is also vital for ecology and environment, since it provides baseflow to many streams, rivers and wetlands. As groundwater is a 'hidden' resource that is typically poorly understood by the public, simple and informative maps can assist to enhance awareness for understanding groundwater and associated environmental issues.

The first national aquifer map for New Zealand (2001) identified 200 aquifers at a scale of approximately 1:5 Million. Subsequently, regional councils and unitary authorities have updated their aquifer boundaries using a variety of methods. However, with increasing demand of groundwater in New Zealand and drought impacts expected to be more significant in the future, more consistent and more advanced aquifer characterisation and mapping techniques are needed to improve our understanding of the available resources.

Significant resources have gone into detailed geological mapping in recent years, and the New Zealand 1:250,000 Geological Map (QMAP) was developed and released as a seamless GIS database in 2014. To date, there has been no national assessment of this significant data set for aquifer characterisation purposes. This study details the use of the QMAP lithological and chrono-stratigraphic information to develop a nationwide assessment of hydrogeological units and their properties.

The aim of this study is to map hydrogeological units in New Zealand, with a long-term goal to use this as a basis for a nationally-consistent map of aquifer systems and aquifer properties (e.g., hydraulic conductivity estimates).

Internationally accepted aquifer mapping studies were reviewed and a method was devised that classifies hydrogeological units based on the geological attributes of the QMAP ArcGIS polygons. The QMAP attributes used in this study were: main rock type; geological age; and secondary rock type. The method was mainly based on values of permeability after global, continental and New Zealand studies. The classification followed a tiered workflow. Tier 1 ('Hydrolithological units') consisted of the classification of only the main rock type, based on median permeability value. Tier 2 ('Hydrogeological units') consisted of a combined classification of main rock type and age, assuming that permeability shows an exponential decay over geological age. Tier 3 ('Hydrogeological units') included all three attributes, where the permeabilities of main and secondary rock types were averaged with weighting. Tier 4 was a simplification of the 10 classes in Tier 3 to four 'Aquifer Potential' classes, i.e. 'Poor', 'Low', 'Medium', and 'High'.

The results show a good match with existing overlaying maps of aquifer boundaries The map is capable of refining aquifer boundaries at the regional scale where these boundaries have not been updated since 2001. Additionally, the map provides a quick and simple way to communicate hydrogeological information. This fundamental dataset is essential for future studies of the impact of climate and humans on groundwater in New Zealand. Future work will include categorising geological system knowledge (e.g., depositional environment) to allow for 3D mapping and characterisation, compilation and incorporation of nation-wide measured hydraulic conductivity values, including uncertainty, and linking with other national data sets.