EGU General Assembly 2020

Online | 4–8 May 2020

HS8.3.5/SSS6.11

Irrigation, soil hydrology and groundwater management for resilient arid and semi-arid agroecosystems

Displays: Wednesday, 06 May 2020, 08:30–10:15 (GMT+2:00)

Conveners & chairpersons: Marco Peli[ECS], Gabriel Rau, Giulio Castelli[ECS], Mark Cuthbert

- In arid and semi-arid areas, the **interaction between surface water management, irrigation practices, soil hydrologic dynamics and groundwater** is key for **sustainable water management, food production and for the resilience of agroecosystems**.

- Their importance goes **beyond the sole technological aspects**, often being connected with some traditional techniques, part of **local cultural heritage**, to be faced with an (at least) **interdisciplinary approach** which involves also humanities.

- On the other hand, **improper land and water management in those areas may contribute heavily to soil degradation and groundwater exploitation**.

This session presents contributions dealing with

- **soil hydrological behaviour;**
- **fluxes between surface and groundwater**;
- the **interaction between irrigation, soil hydrology and groundwater**;
- the design and management of **water harvesting and irrigation systems**, including **oases**;
- the maintenance and improvement of **traditional irrigation techniques**;
- the design of **precision irrigation techniques;**
- **local communities interaction** with water resources;

in arid and water-scarce environments

Display chat plan

- After the introduction, there will be **5 to 7 minutes of dedicated chat time per display;**
- In the time dedicated to each display, **authors are supposed to answer the questions coming from the audience as well as from the conveners;**
- **People interested in the work should check the materials uploaded before the session;**
- An **open discussion of around 30 minutes** will close the chat.

Display chat schedule (link to the uploaded materials behind the display code DXXX)

8:30 Greetings and introduction

8:40 **D400** | EGU2020-8176
Emerging effects of selected rhizosphere properties on transpiration and leaf water potential of two Zea mays L. genotypes in semi-arid environments
Tina Köhler, Daniel-Sebastian Moser, Ákos Botezatu, Jana Kholova, Andrea Carminati, and Mutez Ahmed

Display chat schedule (link to the uploaded materials behind the display code DXXX)

8:47 **D401** | EGU2020-9743
Salinization sources and management strategies in South Africa
Maria Elenius, Alena Bartosova, Jude Musuuza, and Berit Arheimer

8:54 **D402** | EGU2020-12214
Focused groundwater recharge in a dryland environment: hydrometric and isotopic evidence from central Tanzania
David Seddon, Japhet J. Kashaigili, Richard G. Taylor, Mark O. Cuthbert, Lucas Mihale, Catherine Mwihumbo, and Alan M. MacDonald

9:01 **D403** | EGU2020-12855
Drought tolerant quinoa and irrigation scheduling in the Sahel
Jorge Alvar

9:08 **D404** | EGU2020-13581
The dynamics of farmer migration and resettlement in the Dhidhessa River Basin, Ethiopia
Meseret Teweldebrihan, Saket Pande, and Michael McClain

Display chat schedule (link to the uploaded materials behind the display code DXXX)

9:15 **D406** | EGU2020-19140

Hydrogeological controls on groundwater recharge in a weathered crystalline aquifer: A case study from the Makutapora groundwater basin, Tanzania

Emanuel Zarate, Alan MacDonald, Russell Swift, Jonathan Chambers, Japhet Kashaigili, Edmund Mutayoba, Richard Taylor, and Mark Cuthbert

9:22 **D407** | EGU2020-19234

Why studying traditional irrigation?

Stefano Barontini and Barbara Bettoni

9:29 **D408** | EGU2020-20773

Automated water status monitoring in grapevines

Donatella Spano, Mauro Locascio, Serena Marras, Richard L Snyder, Massimiliano Giuseppe Mameli, Daniela Satta, Ana Fernandes de Oliveira, Massimo Barbaro, Paolo Meloni, and Costantino Sirca

Display chat schedule (link to the uploaded materials behind the display code DXXX)

9:36 **D409** | EGU2020-22061
Flood-based Farming as Affected by Hydrological Deficit in the Semiarid Lowlands of Northern Ethiopia
Emnet Negash, **Jan Nyssen**, Girmay Gebresamuel, Tesfa-alem Embaye, Alick Nguvulu, Hailemariam Meaza, Misgina Gebrehiwot, Biadglign Demisse, Tesfaalem Gebreyohannes, and Amanuel Zenebe

9:43 Open discussion and concluding remarks

10:15 End of the chat

Displays which will not be presented (link to the online version behind the display code DXXX)

D399 | EGU2020-3209

Water exchange process and water uptake for irrigated maize cropland in a desert-oasis transition area, Northwest China **not presented**

Yongyong Zhang, Wenzhi Zhao, and Chun Zhao

D405 | EGU2020-13730

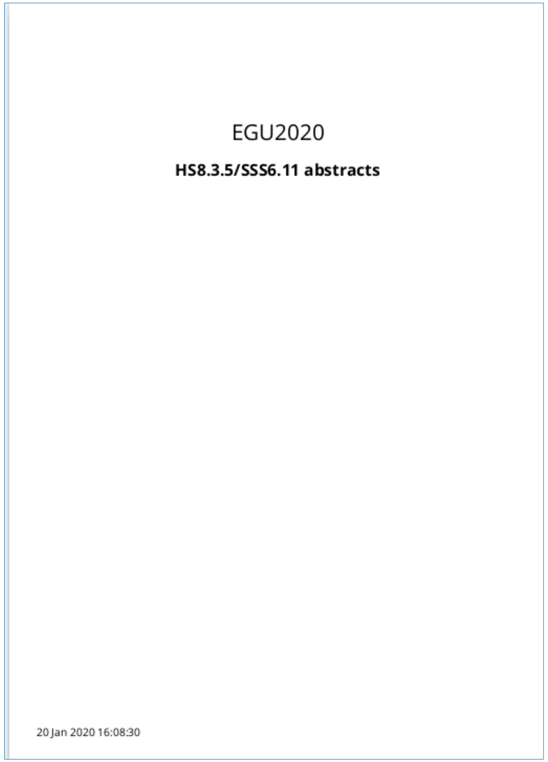
Assessing groundwater sustainability and the influence of water transfer project in Sugan Lake Basin, northwest China **not presented**

Zhengqiu Yang and Litang Hu

EGU General Assembly 2020

Online | 4–8 May 2020

Word cloud analysis on the submitted abstracts



EGU2020

HS8.3.5/SSS6.11 abstracts

20 Jan 2020 16:08:30

EGU2020 is open to anyone interested and is free of charge!

We look forward to your contribution

- towards our discussion
- **on Wednesday, 06 May 2020, 08:30–10:15 (GMT+2:00)**
- after our discussion

Thank you, let's discuss our research in an open and constructive way!

EGU2020

HS8.3.5/SSS6.11 abstracts

22 Apr 2020 09:46:51

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Water exchange process and water uptake for irrigated maize cropland in a desert-oasis transition area, Northwest China

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Soil water and groundwater convert frequently under cropland in a desert-oasis transition area, Northwest China. Crops variedly utilize soil water and groundwater during different growth periods under the cropland with shallow groundwater. The study of water exchange process under irrigated cropland has important significance for regulating the contradiction between water saving and groundwater recharge in the desert-oasis transition area. Soil moisture and soil matric potential at depths ranging from 0 to 70 cm were measured using HydraProbe II and TEROS-21 soil sensors in maize (Zea mays L.) fields in 2019. Stable isotope (δ^2H□$\delta^{18}O$) in different water sources (precipitation, irrigation water, soil water, crop stem, and groundwater) was also measured. The results showed that the groundwater depth varied between 0.57-1.07 m during the maize growth periods. The groundwater depth increased in summer due to the influence of pumped well, while the depth decreased in autumn resulting from the irrigation return water. In the maize growing season, soil moisture and water potential at depths from 10 cm to 30 cm responded to three irrigation times, while soil moisture and water potential below the depth of 50 cm were greater and kept a steady state, which were affected by upward capillary rise of groundwater. The relationship of soil water stable isotope values was $\delta^2H=2.45\delta^{18}O-31.41$, which was lower than the slope of the local atmospheric precipitation line due to the evaporation effect. The soil water stable isotope values at depth of 10 cm varied, while the variation of soil water stable isotope values decreased with the increase of soil depth. The soil water stable isotope values at the depths from 70 to 90cm were close to the groundwater isotope values, which were affected by the groundwater. The stable isotope values in crop stem water were relatively scattered, indicating that the maize used multiple water sources and the water use strategy changed during the growth periods.

EGU2020-8176
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Emerging effects of selected rhizosphere properties on transpiration and leaf water potential of two Zea mays L. genotypes in semi-arid environments

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Understanding the mechanisms that control water use of plants exposed to soil drying and increasing vapour pressure deficit (VPD) has important implications for crop growth in semi-arid regions with low-input agriculture. In particular, the effect of belowground processes on transpiration and stomatal regulation remains controversial. Objective of this study was to understand the role of soil properties and root hairs (as an example of rhizosphere traits) on transpiration and leaf water potential. We hypothesize that root hairs facilitate the water extraction from drying soils, particularly at high VPD, and that this impacts the relation between transpiration rate and leaf water potential. We further hypothesize that stomatal regulation attenuates the drop in leaf water potential when the soil water flow cannot match the transpiration demand and thus emphasizes the importance of root hairs on transpiration rates during soil drying.

We compared maize (Zea mays L.) with (wild-type) and without (mutant) root hairs in three different soil substrates (Alfisol, Vertisol and Sandy Soil). Transpiration and leaf water potential were monitored at varying VPD and soil moistures during soil drying. The hairless mutant showed a higher transpiration in wet soils but declined transpiration at greater water contents as compared to the wild-type. Under well-watered conditions, both genotypes had the highest transpiration rates in Vertisol. In Vertisol, both genotypes closed their stomata at relatively higher water content levels. The relation between transpiration and soil moisture strongly varied between soils. No obvious differences between the genotypes were visible in the relationship between leaf water potential and transpiration. This is explained by the prompt closure of stomata. This study provides experimental evidence of the strong link between stomatal regulation and soil-root hydraulic properties.

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Salinization sources and management strategies in South Africa

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Irrigation practices of various kinds are used in farming all over the world. Especially in cases of over-irrigation and inadequate drainage, evaporation losses can be high and lead to accumulation of minerals in the soils. Water uptake in crops is driven by osmosis, and as such it is reduced or diminished when salt concentrations in the soil water increase. Today, approximately 10 % of irrigated land worldwide has faced diminished production due to salinization, and losses increase every year. There is also concern that global warming can deteriorate production further due to increased evaporation, which should be considered in the light of increasing crop demands with population growth. There is therefore pressing concern to study effects and measures on a global scale.

Continental to global scale hydrological models have emerged in recent years as tools for flood forecasting and estimation of dynamic water fluxes. HYPE is a catchment-based model that simulates rainfall-runoff as well as water quality processes. Recently, an application was developed based on HYPE that covers almost the entire globe, World Wide HYPE (Arheimer et al., 2019). This tool also has great potential for future global assessments of soil salinization under different scenarios.

In this work, a salinization routine was developed in HYPE, whereby salt components follow all main natural hydrological pathways as well as irrigation using groundwater or river flow as a water source. Equilibrium reactions, complexation and cation exchange determine the distribution between dissolved and solid states in the soil. A semi-arid catchment in South Africa with salinization issues (the Crocodile River, Mpumalanga province) was chosen for code development, calibration and verification. Evaluations were based on comparison of simulated and observed mineral concentrations in rivers and groundwater. The model was also tested for all of South Africa.

Detailed analyses of the soil salinity processes were carried out for the Crocodile River catchment. Results show the sensitivity of salinization to hydrological parameters such as recession coefficients, infiltration capacities and macropore flow. This will guide future calibration of the World Wide HYPE model setup. Assessment of the major processes and sources of salinization is performed, and mitigation strategies such as irrigation control and drainage management are tested. Possible regionalization of parameters for global salinization modeling is also suggested based on the results.

Arheimer, B., Pimentel, R., Isberg, K., Crochemore, L., Andersson, J. C. M., Hasan, A., and Pineda, L. (accepted). Global catchment modelling using World-Wide HYPE (WWH), open data and stepwise parameter estimation, Hydrol. Earth Syst. Sci, https://doi.org/10.5194/hess-2019-111, in press, 2019

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Focused groundwater recharge in a dryland environment: hydrometric and isotopic evidence from central Tanzania

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Groundwater, and its replenishment via recharge, is critical to livelihoods and poverty alleviation in drylands of sub-Saharan Africa and beyond, yet the processes by which groundwater is replenished remain inadequately observed and resolved. Here, we present three lines of evidence, from an extensively-monitored wellfield in central semi-arid Tanzania, indicating focused groundwater recharge occurring via leakage from episodic, ephemeral stream discharges. First, the duration of ephemeral streamflow observed from daily records from 2007 to 2016 correlates strongly (R^2 = 0.85) with the magnitude of groundwater recharge events observed and estimated from piezometric observations. Second, high-resolution (hourly) monitoring of groundwater levels and stream stage, established in advance of the 2015-16 El Niño, shows the formation and decay of groundwater mounds beneath episodically inundated adjacent streambeds. Third, stable-isotope ratios of O and H of groundwater and precipitation as well as perennial and ephemeral surface waters trace the origin of groundwater to ephemeral stream discharges. The identification and characterisation of focused groundwater recharge have important implications not only, locally, for protecting and potentially augmenting replenishment of a wellfield supplying the capital of Tanzania through Managed Aquifer Recharge but also, more widely, in understanding and modelling groundwater recharge in dryland environments.

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Drought tolerant quinoa and irrigation scheduling in the Sahel

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Quinoa's resilience to drought stress conditions makes the crop suitable for the Sahel. It can support grain production during the dry season and can be considered an alternative crop for alleviating food insecurity within the region. The modelling of quinoa in new environments, beyond its origin, is required given its rapid worldwide expansion. Crop water models are of interest as pressure on water resources is growing and irrigation scheduling is portrayed as the best option for water optimisation. The AquaCrop model is used to simulate crop's development and derives optimal frequencies and net applications of irrigation. Due to limited water resources in the region, different irrigation schedules (i.e. full irrigation (FI), progressive drought (PD), deficit irrigation (DI) and extreme deficit irrigation (EDI)) are proposed for analysing yield and biomass responses to water stress conditions. Quinoa yields are stabilised under PD, thereby prioritising maximum water productivity rather than maximum yields. When comparing to FI, PD simulations show a 13 % yield reduction (0.97 Mg ha^{-1} for FI vs. 0.85 Mg ha^{-1} for PD), but water savings are as much as 25 % (415 mm for FI vs. 307 mm for PD). Water optimisation is reached by watering less (310 mm) but with more frequent irrigation events (28 rather than 20). The accuracy of model's simulations, as normalised-root-mean-square-error (NRMSE), is of 13.1 % for biomass and 13.6 % for grain yield (average of calibration and validation treatments).

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The dynamics of farmer migration and resettlement in the Dhidhessa River Basin, Ethiopia

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Extensive migration, settlement, and relocation of people for water resources development practice along a river basin often changes its hydrologic conditions and leads to conflicts for available water resources. In view of this, this study compiled the dynamics of population migration, settlement, and water resource developments in the Dhidhessa River Basin (DRB). The trend in migration time series for 1984-2017 based on census data indicates that the migrated rural population were ‘pulled’ by the government initiative. On the other hand, survey revealed that the farmer have dire reasons to migrate from their origin due to the scarcity of land and water. However, given the distance to a dam location, such potential migrants are financially incapable of relocating on their own. The study, therefore, calls for an analysis that takes into account the wellbeing of the displaced agrarian society at large of the migrant population in particular in the dam-affected area.

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Assessing groundwater sustainability and the influence of water transfer project in Sugan Lake Basin, northwest China

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In order to meet the ecological water requirement, a water transfer project that divert river flow from the Sugan Lake Basin to the Dunhuang Basin is under consideration. Inter-basin water diversion project is an effective tool to deal with the uneven distribution of water resources and climate change. However, there is still a lack of research on hydrogeology in the Sugan Lake Basin at present. In this study, FEFLOW software was used to establish a numerical model and it was well calibrated by FEPEST. The result shows that the infiltration of the river surged in 2017–2018 so that the groundwater storage significantly increased in resent year. Under four water transfer scenarios, model was used to predict and analyze the influence of transfer project. When the diversion plan had implemented, the groundwater drawdown gradually increased from west to east in the upstream zone and the gobi zone. The biggest groundwater drawdown were 51.10 m, 56.70 m, 62.34 m and 68.02 m in four transfer conditions. In addition, groundwater level of wetland at most decline by 3.80 m, 4.06 m, 4.30 m and 4.77 m. Water diversion also made a great impact on the spring flow in the basin. The rate of Middle Spring reduced to 0.75×10^8 m^3/a – 0.81×10^8 m^3/a after 100 year, and it would reduce to 0.20×10^8 m^3/a – 0.40×10^8 m^3/a when groundwater system was steady. Nevertheless, the direct discharge from groundwater to lakes basically was not affected. The developed model and results will help to make an effective management of water resources.

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Hydrogeological controls on groundwater recharge in a weathered crystalline aquifer: A case study from the Makutapora groundwater basin, Tanzania

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Drylands (semi-arid/arid regions) represent >35% of the Earth's surface, support a population of around 2 billion people, and are forecast to be increasingly water stressed in coming decades. Groundwater is the most reliable source of water in drylands, and it is likely that the structure and hydraulic properties of superficial geology play a crucial role in controlling groundwater recharge in these regions. However, the spatio-temporal hydrogeological controls on the rates of groundwater recharge, and their sensitivity to environmental change are poorly resolved.

In the Makutapora groundwater basin (Tanzania), an analogue for semi-arid tropical areas underlain by weathered and fractured crystalline rock aquifers, we conducted a series of geophysical surveys using Electrical Resistivity Tomography (ERT) and frequency domain electromagnetic methods (FDEM). Using these data, in conjunction with borehole logs, we identify and delineate five major lithological units in the basin: 1) Superficial deposits of coarse sand (>200 Ω m) 2) Highly conductive smectitic clays (1-10 Ω m) 3) Decomposed pedolitic soils (30-100 Ω m) 4) Weathered saprolite (100-700 Ω m) and 5) Fractured granitic basement (>700 Ω m). We also identify 10-50m wide zones of normal faulting extending across the basin and cutting through these units, interpreted with the aid of analysis of a digital elevation model alongside the geophysics data.

These results are combined with existing long-term hydrological and hydrogeological records to build conceptual models of the processes governing recharge. We hypothesise that: 1) Zones of active faulting provide permeable pathways enabling greater recharge to occur; 2) Superficial sand deposits may act as collectors and stores that slowly feed recharge into these fault zones; 3) Windows within layers of smectitic clay underlying ephemeral streams may provide pathways for focused recharge via transmission losses; and 4) Overbank flooding during high-intensity precipitation events that inundate a greater area of the basin increases the probability of

activating such permeable pathways.

Our results suggest that configurations of superficial geology may play a crucial role in controlling patterns, rates and timing of groundwater recharge in dryland settings. They also provide a physical basis to improve numerical models of groundwater recharge in drylands, and a conceptual framework to evaluate strategies (e.g. Managed Aquifer Recharge) to artificially enhance the availability of groundwater resources in these regions.

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Why studying traditional irrigation?

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In the introduction of his last opus on *The formation of the vegetable mould...* Charles Darwin (1882), regarding the action of worms, stated that "the maxim «de minimis lex non curat» does not apply to science". With this assertion Darwin meant that in the Nature great changes are often a consequence of a continuous and unending repeat of minimal steps. This concept, which throws an intriguing light on all Darwin's opera, may be attractively applied also to describe the evolution of natural ecosystems into agroecosystems and anthropogenic landscapes, particularly in water scarcity conditions. Many historians and archaeologists in fact agree on the fact that the birth of the first cities, as Uruk (ancient Mesopotamia), and the settlement of the great oases along the ancient commercial routes of Central Asia (commonly known as Silk Road), were made possible only thanks to the progressive capability of managing the soil reclamation and irrigation. Such irrigation techniques, which deeply adapted themselves to the local soil and environmental conditions, and were performed to coincide with coherent agricultural practices, permeated the traditional agricultural practice for many centuries until nowadays. Traditional irrigation therefore played a key role at developing anthropogenic landscapes, so that we my regard to them -- in the Darwinian sense -- as to a hydraulic «minimum» of the landscape.

In this contribution, aiming at stimulating a discussion on the state and future of traditional irrigation, with particular reference to the area of the Mediterranean basin and of the Central Asia, we discuss eight conjectures that try to answer to the posed question. They are:

- Traditional irrigation in water scarcity is a cultural and identity heritage;
- However it should not only be preserved, by protecting its most relevant artefacts. In fact it innervates the landscape and provides an important key to understand historical and anthropogenic landscapes, and to reconnect the comprehension of important fluxes of mass, energy and labour;
- It allows the arid agriculture being performed. It is therefore an axle for oases and a defence against desertification;
- It is adaptive and coevolutive with the surrounding environment, and it proved of being able to react to climatic changes;
- Water scarcity conditions may be regarded to as proxies of climatic and hydrological changes also in nowadays humid areas of the Northern Mediterranean basin;
- Traditional irrigation is seldom endogenous. Its capability to diffuse, and to adapt to and to root

in different environments, requires to consider each case both in a local and in an ecumenical perspective;

- It furthermore poses an interesting epistemological question, i.e. whether similar techniques in different contexts were diffused by skilled--labour's migration or treatises, or autonomously developed;
- Finally, it allows to develop labour--intensive landscapes also in marginal and abandoned areas, thus stimulating biodiversity, protecting slopes and mitigating the hydrogeological hazard.

By considering all these conjectures, we might probably conclude that the future of traditional irrigation is yet to be written. The study and the adaptation of the traditional irrigation to modern issues might still deserve important applications to develop agroecosystems in a sustainability perspective.

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Automated water status monitoring in grapevines

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The wine market is increasing in economic importance, so it is crucial for producers to be competitive, efficient, and productive. In addition, climate change requires the adoption of adaptive strategies for a more efficient management of natural resources. Especially in semi-arid regions, the limitation in water availability for crop farming requires adaptive strategies aiming to optimize water productivity. Knowing the optimal moment for irrigation and the water amount to apply is essential information for deficit irrigation of wine grapes. Stem water potential measurements, using the pressure chamber approach, provide an accurate technique for determining plant water status and timing irrigation. In combination with accurate ET measurements, the plant-based measurements offer the information needed to establish water saving deficit irrigation schedules. Collecting stem water potential data, however, is time-consuming and labour-intensive. This work presents the preliminary results of a comparison between new plant-based sensors, which continuously monitor the water status using an automated platform. A field study was conducted on a representative vineyard located in the Mediterranean Basin (Sardinia, Italy). Sensor data were compared to measurements of stem water potential. Two treatments were employed in the experiment: i) mild to moderate water stress conditions were applied from fruit set until ripening; ii) no irrigation from bunch closure until harvest, which resulted in moderate to severe water deficit conditions. In both treatments, stem water potential measurements were monitored weekly on adult leaves with a pump-up pressure chamber, while the T-Max method was used to determine the xylem sap flow. Leaf thickness, an indirect measurement of leaf turgor, was measured with a commercial sensor. Preliminary results showed a good potential for these promising techniques that may monitor proxies of the vine water status in an automated way, giving useful and user-friendly information for planning efficient irrigation schedules. In addition, micrometeorological measurements provide a method for assessing the actual ET rates between irrigation events, and this effort will be studied in future field experiments. Preliminary results showed a good potential for these promising techniques that may monitor proxies of the vine water status in an automated way that, in conjunction with reliable ET estimates, provide the information needed to determine user-friendly information for

planning efficient irrigation schedules for deficit irrigated wine grapes.

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Flood-based Farming as Affected by Hydrological Deficit in the Semiarid Lowlands of Northern Ethiopia

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Agriculture remains the dominant source of food production and the livelihood foundation for majority of the rural poor in the sub-Saharan Africa, including Ethiopia. Access to agricultural-water is, however, a limitation hindering crop productivity and end food insecurity in the drylands. In rain-deficit lowlands such as in the Raya-valley, flood-based farming is a means of improving crop production. Such spate irrigation systems grow in importance; though the effects of headwater hydrological deficit on flood-farming systems are lacking evidence. The present work investigates the impacts of headwater hydrological deficit on spate-irrigated agriculture in Tsge'a spate systems. Canal length and area of spate-irrigated agriculture along Guguf river for the 1980s and 2010s were tracked using Global Positioning System; while runoff trend analysed using linear regression. Annual volume of flash-flood shrunk by 7.36×10^{6} m^{3}. This is mainly due to changing climate and increasing water retention by the soil and humans at the escarpment. As a result, length of canals and area of spate-based farms downstream declined by 1.37 km (35%) and 1540 ha (57.5%), respectively, only in three decades time. This corresponds to an average withdrawal of -44 ha yr^{-1}. A 1×10^{6} m^{3} decline in flash-flood caused a 366.4 ha decline in spate-based farms. Moreover, farm fields located next to the river course are less affected, as compared to farms on the tail of the scheme. If the current trend continues, there is likely a high risk that the remaining farms currently receiving flood may run out of spate systems. Therefore, flood management technologies are needed to optimize the efficiency of soil moisture in the spate system.

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