Connectivity of rainfall and human activity impacts on soil erosion processes in Mediterranean vineyards

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Connectivity of rainfall and human activity impacts on soil erosion processes in Mediterranean vineyards.

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Host: Prof. Dr. Artemi Cerdà,

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INTRODUCTION

The vineyards have exceeded their original ecological limits and come to occupy lands with critical natural conditions such as steep slopes, dry climates or high soil erosion rates (Molinero Hernando, 2012; Prosdocimi et al., 2016; Salome et al., 2014). However, viticulture areas are maintaining their economic and social relevance (Leeuwen et al., 2004; Martínez-Casasnovas et al., 2010).

Traditional vineyards are planted along contour lines or using small terraces with moderate slopes supported by long rows of plants (Ramos and Porta, 1997; Sofia and Tarolli, 2017). All these systems are leading to increase grape and wine production, but enhancing land degradation due to soil erosion (López-Piñeiro et al., 2013). The extreme rainfall events, commonly when the soil is unprotected without leaf´s cover, and non-suitable land management are increasing the impact of runoff and soil detachment (García-Díaz et al., 2017; Novara et al., 2011; Rodrigo-Comino et al., 2017). Thus, the risk of catastrophic floods or spreading of chemicals by overland flow, the decrease of water availability for the vines and the nutrient losses could be impossible to stop (Calleja-Cervantes et al., 2015; Leonard and Andrieux, 1998; Novara et al., 2013).

The negative impact and variability of soil erosion at intra-plot scale in vineyards is well known by researchers (Chevigny et al., 2014; Rodrigo Comino et al., 2016a) and farmers (Bramley and Hamilton, 2004; Marques et al., 2015), but not easy to estimate at long-term periods to develop suitable land management plans (Keesstra et al., 2016).

To achieve this goal, stock unearthing method (SUM) is considered as a useful methodology. The SUM has been shown to be a reliable method to estimate erosion rates and spatial evolution of the topsoil from pluri-annual to pluri-decennial time scales in vineyards (Brenot et al., 2008; Casalí et al., 2009; Paroissien et al., 2010). This method is highly similar to dendro-geomorphology methods because it is based on the measurement of the distance from the topsoil to the grafted vine stock union, confirmed as a passive indicator of topsoil movements since the initial planting of vine stock. This method is able to estimate erosion rates at temporal scale sufficiently long to evaluate the cumulate effects of tillage practices, but also to show the spatial distribution of the sediment detachment, transport and deposition under natural rainfall events. The most recent studies have tested its accuracy by comparing their results with digital elevation models, GPS and ortophotography (Biddoccu et al., 2017; Chevigny et al., 2014; Quiquerez et al., 2014) or with sediment collectors and plants with different ages (Rodrigo Comino et al., 2016b). However all of these studies assumed the main weakness of this method: the assumption that the topsoil surface between the measurements remains almost planar without a generation of uncertainty due to roughness by rills, footpaths, and wheel tracks.

Therefore the main goal of this methodological research proposal was to develop a new improvement of the SUM, but being easy to carry out for larger scales and different study areas or problematics in vineyards. To achieve this goal, three chosen rows at different slope positions (shoulder, backslope and footslope) in a one conventional vineyard of Eastern Spain were tested by using the improved unearthing stock method (ISUM) and the traditional one (SUM).

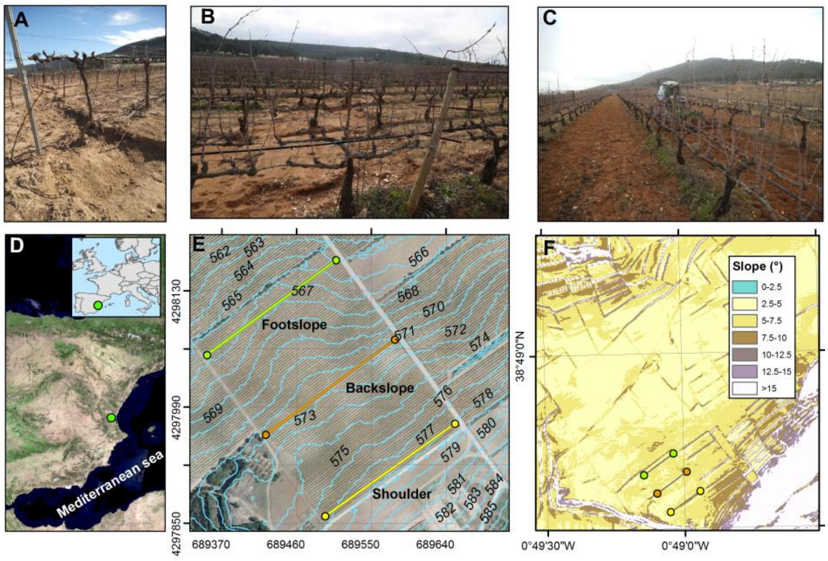
WORK CARRIED OUT DURING STSM

During the stay at the test site Celler del Roure (Valencia, Spain) monitored by the host, Prof. Dr. Artemi Cerdà, the focus was set on the collection of data and samples. In addition, the limits and the suitability of all methods were discussed by all persons involved.

TEST SITE

The vineyards are situated in a traditional viticulture region of the Terres dels Alforins Valencia province (Valencia, Eastern Spain). The experimental areas are located in Les Alcusses valley within the Moixent municipality. We have analysed old plantation on colluvium lithology and marls with different ages and land managements. In Fig. 1, it is showed an example of one studied area, a vineyard planted with a Monastrell grape variety, which are 25 year old with a plantation framework of 3.0 x 1.4 m (≈130 vines).

Fig. 1. Study area



The soils were classified as Terric Anthrosol (IUSS Working Group WRB, 2014). The observed soil profiles reach from 40 to 60 cm depth and are homogeneous due to the millennia of ploughing. Clear signals of soil compaction can be observed from 20 cm depth.

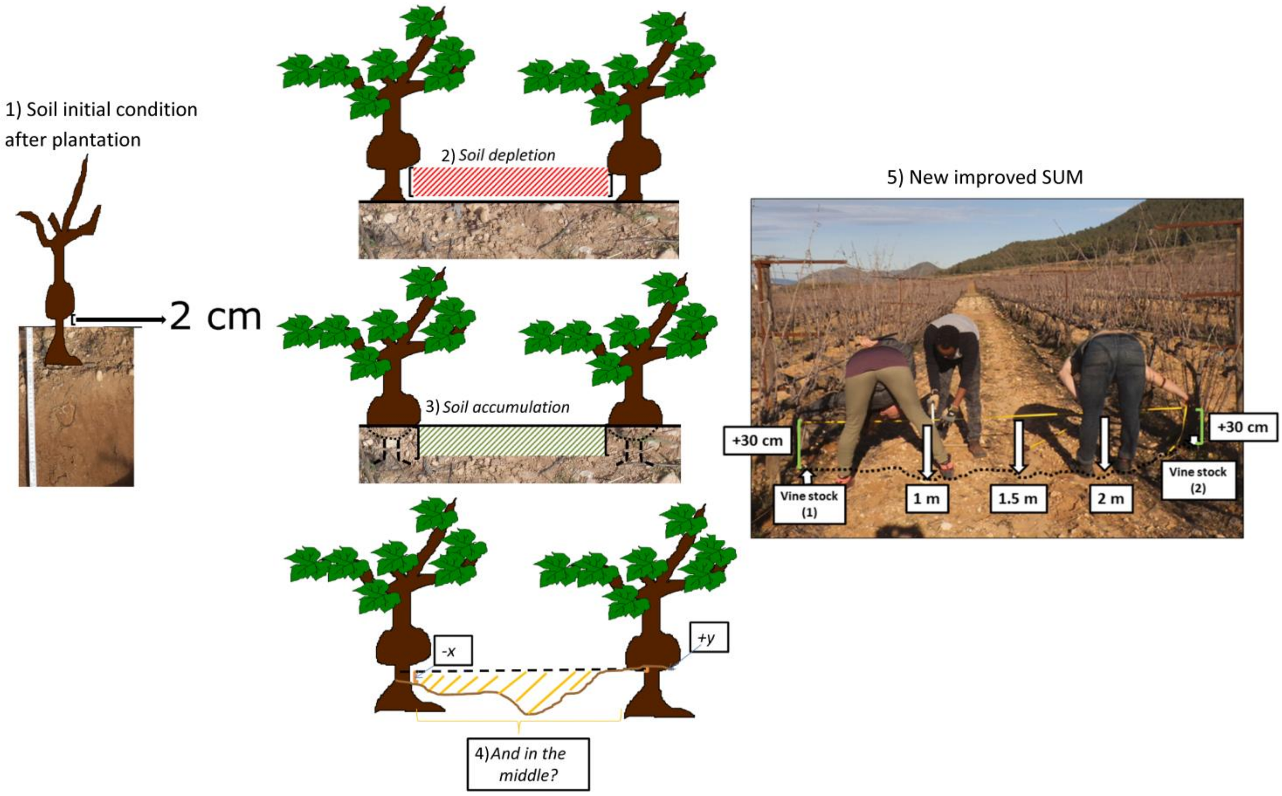
Rills and ephemeral gullies, slides and floods can be noted after extreme rainfall events of 20 mm in 30 minutes or 30 mm in 60 minutes which have a 2-year return period.

METHODS & PRELIMINARY RESULTS: NEW CHANGES FROM SUM TO ISUM

The stock unearthing method (SUM) is characterized by measuring the distance between frontal marks on the graft union (visible on grape vines) and the soil surface. The graft union shows an unearthing or buried signal, which reflects the initial distance between the vine stock and the actual topsoil level at the date of observation. Before the plantation, soil was levelling and the plants are situated in micro-terraces relatively flat. When manually planting in relatively flat soils, the graft union (mechanically by the nurseryman prior to planting) is placed from 2 cm to avoid soil moisture, freezing, and fungus. The distance of the graft union does not use to change since the plantation (Brenot et al., 2008; Casalí et al., 2009); only the new part corresponding to the new grape variety will grow (Fig. 2a). Therefore, changes from the theoretical initial conditions due to depletion (Fig. 2b) or accumulation (Fig. 2c) situations can be estimated. Therefore, prior it was to obtain the confirmation of the conditions described by Brenot et al. (2008) with the vine growers and during the field work such as the unappreciable vertical growth of the graft union after planting and the proof of the initial elevation as constant at a parallel control plot with new vines (initial distance = 2 cm).

In the past, the performed investigations claimed that the main limit of this method is that it was established on the assumption that the topsoil surface remains almost planar (Fig. 2b and Fig.2c), without a generation of uncertainty due to roughness by rills, footpaths, and wheel tracks (Fig. 2d). Logically, this situation is not always so. Therefore, we want to purpose an easy and fast improvement of this method by including, at least, three measure points within the inter-row. From the vine stock graft union, we lift 30 cm in each vine and with a meter band join both rows (Fig. 2e). This lifting was carried out in every measure to allow joining possible buried vine stocks (positive measures) and discovered ones (negative measures). Thus, we delineate two points to 1 meter of distance and directly in the middle (1.5 m) from both plants on the inter-row. Thereby, we are working to be able to: i) generate DEMs (digital elevation models) without extrapolation methods only by using our measured points, b) increase the accuracy and precision of our final maps and soil erosion rate estimations; and, c) detect some linear processes such as rills, accumulations or mass transports. We decided to call this methodological change as ISUM or improved stock unearthing method.

Fig. 2. ISUM description



The distance of graft unions from the end part of the graft union to the actual topsoil level at three different slope positions in all studied areas were measured always by the same person: shoulder, backslope and footslope. If the high roughness generated little steps or the grass cover limited the visibility of the point, these were carefully eliminated to level the soil with the nearby current topsoil level. After measuring the graft union, three more points were delineated. Therefore, for every paired vine, we had 5 points. That meant that each map and soil erosion estimation were carried out by using approximately more than 600 points. In total, 4160 points were measured. For the final estimations, an addition of 2 cm was applied to all the measurements, corresponding to the initial graft union distance.

To represent the actual topsoil level of the surface in 2017 (February), a digital elevation model (DEM) of each slope position by using the tool “Topo to raster” of the software ArcMap 10.4 (ESRI) was generated. The resultant maps with an accuracy of centimetres can be applied to assess the spatial structure of erosion processes.

Finally, an estimation of the total soil loss calculated in Mg ha^{-1} yr^{-1} was obtained using the volume differences. The sides of each polygon were delimited as the distance between each graft union (3 m) and the average of point measures (5): 1.4 x 0.6 m. The height corresponded to the distance between the botanic marks and the measured point within the inter-row (Fig. 2e). Finally, total soil loss can be estimated from the erosion–deposition (ER) equation proposed by Paroissien et al., (2010):

$ER = Vol x Ds/(St \times Av)$

Where the volume (Vol), the total area field (St), the age of the vines (Av; 25 years) and the bulk density data (Ds) were applied. Bulk density for all the study areas were calculated, which is the average of the soil samples collected with a steel cylinder (1 cm^{-3}) from different depths (0–5 and 5–15 cm) and slope positions (n=7).

UPCOMING WORK

Post processing of the data is still working at Málaga and Trier Universities and shared with the host, Prof. Dr. Artemi Cerdà. This includes the raw data, as well as the incorporation of the results of mapping (e.g. Fig. 3) and calculations into the common soil erosion rates (Table 1), by comparing the old and new methods.

The first results will be presented at the meeting of EGU in Vienna with an oral presentation end of April and submitted in the journal of Ecological indicators (Elsevier).

Fig. 3. ISUM map

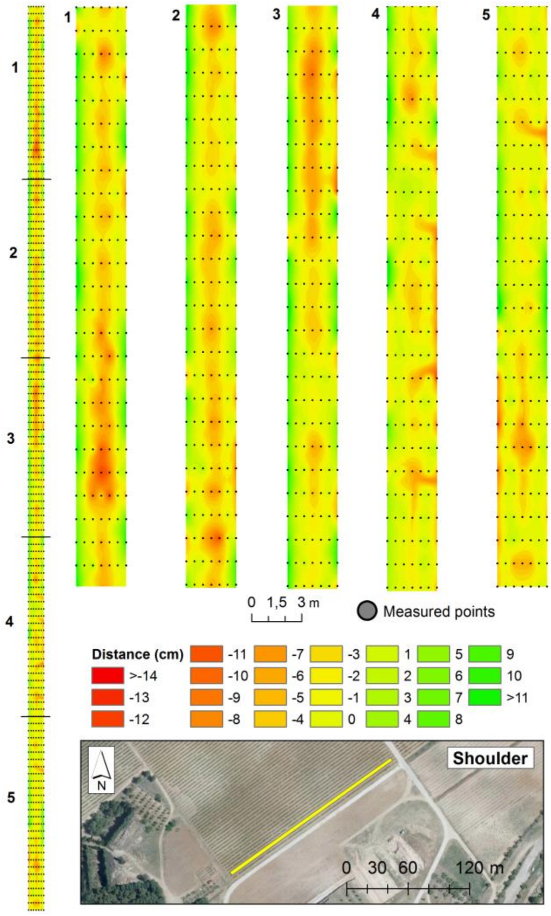


Table 1. Soil erosion results comparison using the ISUM and TSUM

		ISUM	TSUM	Diff. (ISUM-TSUM)
Shoulder	m^3	-1.9	7.1	+9
	Mg ha^{-1}	-2.3	8.7	+11
	Mg ha yr^{-1}	-1.6	6.1	+7.7
Backslope	m^3	3.3	9.1	+5.8
	Mg ha^{-1}	4.1	11.1	+7.2
	Mg ha yr^{-1}	2.8	7.7	+4.9
Footslope	m^3	15.6	20.8	+5.2
	Mg ha^{-1}	19.2	25.6	+6.4
	Mg ha yr^{-1}	13.3	17.7	+4.4

ISUM: improved stock unearthing method; TSUM: traditional stock unearthing method; Diff.: Differences between improved and traditional stock unearthing methods.

CONTRIBUTION OF THE WORK TO THE ACTION AIMS

The methodology was really fast and relatively easy to be applied in the studied vineyards. ISUM has not been applied in South Mediterranean areas and under different land management and ages ever, representing a new and great advance in the present soil science and for enterprises/farmers. Moreover, for future connectivity studies represent a useful tool to asses topsoil redistribution and water flux direction at field and catchment areas. This research will represent a new example of cheap research, but with useful and novelty results.

The incorporation of the registered results from this research will clearly contribute and help to the WP2 (measuring), WP3 (modeling) and WP5 (society).

In addition, the STSM contributed successfully to an exchange in knowledge about measurement methods, land and soil management systems across disciplines as agricultural and cartography engineers and physical geographers.

PERSONAL BENEFITS OBTAINED DURING THE STAY

I have learnt a lot of with the research group of Valencia to analyze soil erosion processes and connectivity directly in field. Maybe, the most important benefit was that with Prof. Dr. Artemi Cerdà, who has a long experience in this topic, I completed with exist all the explained deliverables and I could learn a lot about his experiences in field work and with farmers.

Finally, I think that in the future I can apply the new acquired skills in the final steps of my PhD

Thesis and to strengthen with new ideas my own line of research in vineyards.

***A letter from Prof. Dr. Artemi Cerdà from University of Valencia confirming the successful execution of the STSM is attached.

REFERENCES

1. Biddoccu, M., Zecca, O., Audisio, C., Godone, F., Barmaz, A., Cavallo, E., 2017. Assessment of long-term soil erosion in a mountain vineyard, Aosta Valley (NW Italy). Land Degrad. Dev. doi:10.1002/ldr.2657
2. Bramley, R. g. v., Hamilton, R. p., 2004. Understanding variability in winegrape production systems. Aust. J. Grape Wine Res. 10, 32–45. doi:10.1111/j.1755-0238.2004.tb00006.x
3. Brenot, J., Quiquerez, A., Petit, C., Garcia, J.-P., 2008. Erosion rates and sediment budgets in vineyards at 1-m resolution based on stock unearthing (Burgundy, France). Geomorphology 100, 345–355. doi:10.1016/j.geomorph.2008.01.005
4. Calleja-Cervantes, M.E., Fernández-González, A.J., Irigoyen, I., Fernández-López, M., Aparicio-Tejo, P.M., Menéndez, S., 2015. Thirteen years of continued application of composted organic wastes in a vineyard modify soil quality characteristics. Soil Biol. Biochem. 90, 241–254. doi:10.1016/j.soilbio.2015.07.002
5. Casalí, J., Giménez, R., De Santisteban, L., Álvarez-Mozos, J., Mena, J., Del Valle de Lersundi, J., 2009. Determination of long-term erosion rates in vineyards of Navarre (Spain) using botanical benchmarks. Catena 78, 12–19. doi:10.1016/j.catena.2009.02.015
6. Chevigny, E., Quiquerez, A., Petit, C., Curmi, P., 2014. Lithology, landscape structure and management practice changes: Key factors patterning vineyard soil erosion at metre-scale spatial resolution. CATENA 121, 354–364. doi:10.1016/j.catena.2014.05.022
7. García-Díaz, A., Bienes, R., Sastre, B., Novara, A., Gristina, L., Cerdà, A., 2017. Nitrogen losses in vineyards under different types of soil groundcover. A field runoff simulator approach in central Spain. Agric. Ecosyst. Environ. 236, 256–267. doi:10.1016/j.agee.2016.12.013
8. IUSS Working Group WRB, 2014. World Reference Base for Soil Resources 2014, World Soil Resources Report. FAO, Rome.
9. Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A., Cerdà, A., 2016. Effects of soil management techniques on soil water erosion in apricot orchards. Sci. Total Environ. 551–552, 357–366. doi:10.1016/j.scitotenv.2016.01.182
10. Leeuwen, C. van, Friant, P., Choné, X., Tregoat, O., Koundouras, S., Dubourdieu, D., 2004. Influence of climate, soil, and cultivar on terroir. Am. J. Enol. Vitic. 55, 207–217.
11. Leonard, J., Andrieux, P., 1998. Infiltration characteristics of soils in Mediterranean vineyards in Southern France. Catena 32, 209–223. doi:10.1016/S0341-8162(98)00049-6
12. López-Piñeiro, A., Muñoz, A., Zamora, E., Ramírez, M., 2013. Influence of the management regime and phenological state of the vines on the physicochemical properties and the seasonal fluctuations of the microorganisms in a vineyard soil under

semi-arid conditions. Soil Tillage Res. 126, 119–126. doi:10.1016/j.still.2012.09.007

13. Marques, M.J., Bienes, R., Cuadrado, J., Ruiz-Colmenero, M., Barbero-Sierra, C., Velasco, A., 2015. Analysing perceptions attitudes and responses of winegrowers about sustainable land management in Central Spain. Land Degrad. Dev. 26, 458–467. doi:10.1002/ldr.2355
14. Martínez-Casasnovas, J.A., Ramos, M.C., Cots-Folch, R., 2010. Influence of the EU CAP on terrain morphology and vineyard cultivation in the Priorat region of NE Spain. Land Use Policy 27, 11–21. doi:10.1016/j.landusepol.2008.01.009
15. Molinero Hernando, F., 2012. Los paisajes del viñedo en Castilla y León: tradición, renovación y consolidación. Polígonos Rev. Geogr. 0, 85–117. doi:10.18002/pol.v0i21.27
16. Novara, A., Gristina, L., Guaitoli, F., Santoro, A., Cerdà, A., 2013. Managing soil nitrate with cover crops and buffer strips in Sicilian vineyards. Solid Earth 4, 255–262. doi:10.5194/se-4-255-2013
17. Novara, A., Gristina, L., Saladino, S.S., Santoro, A., Cerdà, A., 2011. Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. Soil Tillage Res. 117, 140–147. doi:10.1016/j.still.2011.09.007
18. Paroissien, J.-B., Lagacherie, P., Le Bissonnais, Y., 2010. A regional-scale study of multi-decennial erosion of vineyard fields using vine-stock unearthing–burying measurements. Catena 82, 159–168. doi:10.1016/j.catena.2010.06.002
19. Prosdocimi, M., Cerdà, A., Tarolli, P., 2016. Soil water erosion on Mediterranean vineyards: A review. Catena 141, 1–21. doi:10.1016/j.catena.2016.02.010
20. Quiquerez, A., Chevigny, E., Allemand, P., Curmi, P., Petit, C., Grandjean, P., 2014. Assessing the impact of soil surface characteristics on vineyard erosion from very high spatial resolution aerial images (Côte de Beaune, Burgundy, France). Catena 116, 163–172. doi:10.1016/j.catena.2013.12.002
21. Ramos, M.C., Porta, J., 1997. Analysis of design criteria for vineyard terraces in the mediterranean area of North East Spain. Soil Technol. 10, 155–166. doi:10.1016/S0933-3630(96)00006-2
22. Rodrigo Comino, J., Quiquerez, A., Follain, S., Raclot, D., Le Bissonnais, Y., Casalí, J., Giménez, R., Cerdà, A., Keesstra, S.D., Brevik, E.C., Pereira, P., Senciales, J.M., Seeger, M., Ruiz Sinoga, J.D., Ries, J.B., 2016a. Soil erosion in sloping vineyards assessed by using botanical indicators and sediment collectors in the Ruwer-Mosel valley. Agric. Ecosyst. Environ. 233, 158–170. doi:10.1016/j.agee.2016.09.009
23. Rodrigo Comino, J., Ruiz Sinoga, J.D., Senciales González, J.M., Guerra-Merchán, A., Seeger, M., Ries, J.B., 2016b. High variability of soil erosion and hydrological processes in Mediterranean hillslope vineyards (Montes de Málaga, Spain). Catena 145, 274–284. doi:10.1016/j.catena.2016.06.012
24. Rodrigo-Comino, J., Senciales González, J.M., Ramos, M.C., Martínez-Casasnovas, J.A., Lasanta Martínez, T., Brevik, E.C., Ries, J.B., Ruiz-Sinoga, J.D., 2017. Understanding soil erosion processes in Mediterranean sloping vineyards (Montes de Málaga, Spain). Geoderma 296, 47–59. doi:10.1016/j.geoderma.2017.02.021
25. Salome, C., Coll, P., Lardo, E., Villenave, C., Blanchart, E., Hinsinger, P., Marsden, C., Le Cadre, E., 2014. Relevance of use-invariant soil properties to assess soil quality of vulnerable ecosystems: The case of Mediterranean vineyards. Ecol. Indic. 43, 83–93. doi:10.1016/j.ecolind.2014.02.016

26. Sofia, G., Tarolli, P., 2017. Hydrological response to ~30 years of agricultural surface water management. Land 6, 3. doi:10.3390/land6010003