EIP-AGRI Focus Group

Nature-based Solutions for water management under climate change

Minipaper: Nature-based Solutions at the field scale

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INTRODUCTION – MOTIVATION

According to IUCN (International Union for Conservation of Nature), Nature-based Solutions are "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". This minipaper focuses on NbS that could potentially be applied by farmers at the field scale to improve water management, as both were identified by the Focus Group as the most promising cost-effective practices. Although other NbS at the field scale exist, this paper is focused on sustainable farming practices for improving water availability at the farm level. Terracing is not treated in this paper because we considered it as an infrastructure more than a farming practice.

According to Miralles-Wilhelm, F. (2021) the concept of Conservation Agriculture is considered as a Nature-based Solution (NbS), which, beyond reduction in farm operation costs, improved nutrient use efficiency, crop yield stability and the delivery of soil-mediated ecosystem services, can also modify soil water dynamics (Corsi and Muminjanov, 2019). The principles of Conservation Agriculture can be summarized as follows:

- Minimum mechanical soil disturbance (no-till)
- Permanent soil organic cover (by cover cropping and retaining cover crop and/or pruning residues on the soil surface)
- Species diversification (crop rotations/associations/inter-cropping)

Another NbS at the field scale is to adopt a Keyline pattern cultivation, which consists of subsoil ripping (without inverting the soil) along the contour lines forming a sort of small ditches to slow down run-off flow while harvesting water across the landscape, controlling soil erosion and runoff and optimizing the intake and consequent utilization of water resources (Yeomans 1958). The key line cultivation pattern can be combined with swales, *i.e*, shallow trenches which are also dug along the contour lines for water harvesting. Even if it is not referred to in FAO book "Nature-based solutions in agriculture: Sustainable management and conservation of land, water, and biodiversity" (Miralles, 2021), we can consider it as an NbS regarding water management because Keylines design use natural keypoints and keylines in the field and the objective is to enhance water retention and reduce soil erosion.

We are going to look at those systems in relation to their effects on soil water. We can resume water fluxes at field level according to figure 1 (Basch et al., 2012)

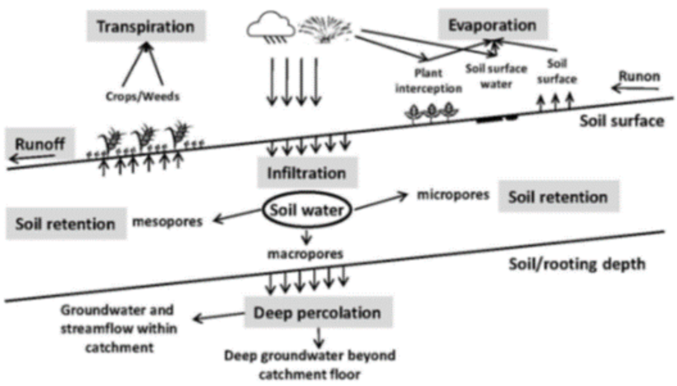

Figure 1: Water fluxes over a landscape or watershed and destinations of rain and irrigation water

Water storage capacity of a soil is ultimately a function of its depth and texture but can also be influenced by its management and resulting structure and pore size distribution (table 1).

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Table 1: Total Porosity, Pore Size Distribution, Plant-Available Water, and Soil Organic Matter Content in a Vertic Cambisol after 6 Years under No-Till (NT) and Conventional Tillage (CT) (Carvalho and Basch (1995))

Tillage	Depth (cm)	>50 µm (%)	50–10 µm (%)	10–0.2 µm (%)	<0.2 µm (%)	Total Porosity	Available Water (%)	SOM (g/kg)
NT	10	3.20	2.22	2.7	38.37	46.52	4.92	2.53
	20	0.86	3.91	5.22	36.16	46.15	9.13	2.15
	30	1.86	2.63	11.48	29.44	45.40	14.11	2.25
	0–30	1.97	2.92	6.47	34.66	46.02	9.39	2.31
CT	10	15.08	2.34	4.36	29.95	51.73	6.71	1.58
	20	2.67	1.32	2.31	39.95	42.25	3.63	1.7
	30	1.47	1.56	3.29	35.62	41.94	4.85	1.66
	0–30	6.41	1.74	3.32	35.17	45.31	5.06	1.65

Effect of these practices on water quantity

Conservation Agriculture

Soil management based on Conservation Agriculture practices affects soil water by its impacts on infiltration, runoff, evaporation, pore size distribution and soil organic matter content. It is well known that the combination of no-till and a permanent soil cover improve water infiltration and thus reduce runoff (Landers et al. 2007) (figure 2), minimize water evaporation from soil, and contribute in the medium and long-term to change pore size distribution favouring the volume of plant available water in mesopores (50 - 0.2 µm) (table 1, Carvalho and Basch, 1995), and to an increase in soil organic matter (Hudson, 1994).

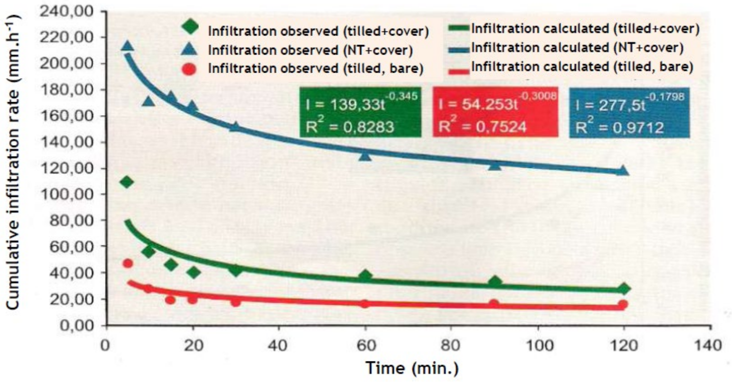
Cover crops influence water dynamics by modifying soil porosity. They help reduce soil evaporation but, at the same time, they use water to grow. N. Meyer (**BAG'AGES project, 2019**) showed that cover crop introduction reduces in average winter drainage by 30 mm. This means that their impact in terms of water availability for the following cash crop depends on spring's rain and it is important to think of water availability at a crop rotation level.

A field trial conducted in the west of France between 2017 and 2019 (Arvalis, 2021) comparing four farming systems (bare soil / mulch / cover crop destroyed 3 weeks before sowing / cover crop destroyed just before sowing) concluded that the mulch treatment could keep more humidity than the other farming practices. This result confirms both the findings of Klocke et al., (2009) (table 2) and the conclusions of the **ACUAsave project** carried out in South Portugal (Water use efficiency and Conservation Agriculture – 2017 / 2019), which showed an evaporation reduction correlated to soil cover obtained through residues of the previous crop and those of the cover crop that caused the initial lower soil moisture under no-till (figure 2).

Table 2. % of soil cover and evaporation reduction (adapted from Klocke et al., 2009)

Soil cover (%)	Relative potential evaporation
0	1
10	0.9
20	0.78
30	0.7
40	0.67
80	0.58

Conservation Agriculture (CA) has also an effect on water infiltration rate. Data provided from a Brazilian experience with three different soil management systems (tilled + cover / no till + cover / tilled + bare) show a significant increase of water infiltration rate when the combination of no-



till and soil cover is applied (figure 3).

Figure 3. Cumulative water infiltration rate for 3 systems (Landers et al., 2007)

ACUAsave project showed a higher humidity in soil profile under Conservation Agriculture than Conventional tillage at the end of the season (figure 3).

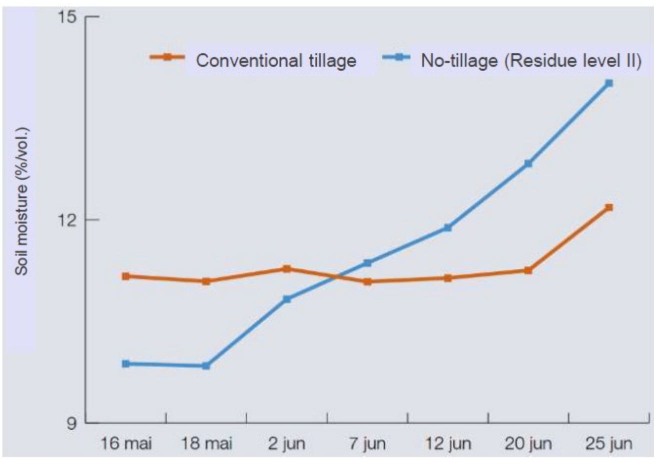


Figure 2. Differences in soil moisture in the layer 0–60 cm (Coruche) – ACUAsave project (Basch et al., 2022)

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However, in **BAG'AGES project**, water storage capacity is only little improved by conservation agriculture (max one day ETP covering more than a conventional system in a French climate). One of the main hypotheses is that it is not water storage capacity which increase in those systems but an improvement in water dynamics due to soil porosity evolution. It would mean that there is not more water in the soil, but the water is easier to get for the crop.

In the medium and long-term Conservation Agriculture can modify pore size distribution. Carvalho and Basch (1995) found an 86% increase of the volume of mesopores (available water) in the 0-30cm soil layer after six years of differentiated soil management of a Vertisol in South Portugal (table 1).

Keyline design

A Keyline pattern cultivation consists of subsoil ripping (without inverting the soil) along the contour lines to slow down run off flow while acting as micro water management storage ditches across the landscape. The main goal is to control erosion and increase soil water storage capacity. This farming practice can be adopted in both woody and herbaceous cropping systems under rainfed and irrigated conditions and in combination with other practices such as swales, which are shallow trenches dug along the contour lines for water harvesting. Trees can be planted directly downhill of each swale, so that when it rains and the swales fill up, the rain sinks slowly into the soil directly into the roots of the trees. A good example where these practices are being adopted in a rainfed almond field is La Junquera farm in South-eastern Spain. In this case, the keyline pattern cultivation was adapted to local conditions by combining it with swales to facilitate machinery works.

Although these practices require an initial investment and maintenance, implementation costs can be offset after few years as the farm increases its water availability and productivity, with the possibility of cultivating a secondary crop along the swales, and reduces soil, carbon, and nutrient losses by erosion (Foppe , 2019; Burholt 2019).

Effect of these practices on water quality

Water quality as affected by agriculture is mainly caused by sediments, nutrients, as well as organic matter and pesticides. Whereas all these substances play a role for surface water bodies, groundwater is mainly affected by nutrients and pesticides. Runoff and erosion are by far the most important pathway for the off-site transport of these contaminants from agricultural fields reaching in many cases surface water bodies. Both runoff and even much more significantly its sediment load can be decisively reduced through the continuous application of CA principles (Holland, 2004, Magdoff and Van Es, 2021) and by Keylines design (Panigrahi et al 2007; Chaplot et al 2019).

Regarding the downward movement of nutrients and pesticides, the higher water intake (higher infiltration and reduced runoff) in CA systems is not correlated with more transport of these substances down the soil profile. This can be the result of different causes. Surface applied pesticides are retained by crop residues on top of the soil where they are subject to higher degradation either through volatilization and solar radiation, or through higher microbial activity in the topsoil after being washed off the residues. Apart of the consequent lower amount of contaminant available, the leaching of the contaminants was also found to be reduced as much of the water appears moving through the soil in macropores thus bypassing the soil matrix (preferential flow) (Kanwar et al., 1985, Düring et al., 1998, Kassam, 2020).

S. Cueff (**BAG'AGES project**, 2020) compared conventional systems and conservation systems and their effect on leaching of pesticides. Here are her main conclusions "Leaching experiments were conducted on undisturbed soil columns to assess the influence of cropping practices on three pesticides (metaldehyde, nicosulfuron and mesotrione) behaviour. Pesticide transfer mainly depended on pesticide properties and soil type with only little effect of cropping practices (under the laboratory conditions tested) ...

Example of a farm in transition

Peter's family farm covers 75 ha and produces cabbage on 8 ha as main product over 25 years. It is located in Slovakia, sub-Tatra basin 650-700 m ASL. This is an example of Conservation Agriculture. Here is Peter's observations:

"To adapt to climatic change, we are moving to apply Conservation Agriculture principles on cabbage growing to eliminate soil erosion and improve water management. In 2019, in a first test we used cereal rye as cover crop that was rolled in bloom phase and transplanted with cabbage. Cabbage in cereal rye didn't grow as desired due to rye allelopathy and nutrients depletion. In fall 2019 cereal rye, crimson clover, white clover and hairy vetch were sown to test cover crops. Rye and hairy vetch survived winter. In June 2020 the cover crops were rolled with roller crimper and cabbage transplanted in rolled mulch. Cabbage in hairy vetch, right from the beginning, grew a bit slower than cabbage in conventional system, but in the later phase, when heads were formed it grew faster. Observed advantage over conventional growing was health of plants, lower insects' pressure, balance of soil humidity under mulch cover and absence of soil crust. Problems occurred with vetch termination, when some vetch that survived rolling competed and formed seeds, but blooming vetch mask cabbage or repel from insects. Rye as cover crop for cabbage inter-transplanting showed bad results again. For further cover crop selection, we decided to use crimson clover, because it blooms 2 weeks earlier than hairy vetch and crimson clover has no climbing stem crop resulting in some competition problems in the 2020 test. For season 2021 and 2022 we failed to establish crimson clover as the cover crop due to harsh weather condition and some missing knowledge, but in 2021 we have been testing a new no-till transplanter from Checchi & Magli integrated with a roller crimper."

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Identifying needs from practice and proposals for further research

NbS at field scale can affect water dynamics and water availability for the crops depending on agro-climatic conditions. Modelling and validation efforts but also monitoring efforts (in situ estimations) need therefore to be undertaken in different agro-climatic regions to estimate the degree of how the practice can impact water availability and thus water scarcity resilience under climate change.

The research themes can be identified within two scientific domains: agronomy and agricultural engineering. All research on the scientific and technical aspects must also consider the economics for farmers to adopt the practices and any regulatory barriers they may face.

Agronomic research topics should address:

- the local pedoclimatic conditions and socio-economic context for the success of NbS agricultural practices -> it is important to understand which NbS can be a success in which conditions. Europe has so many pedoclimatic conditions and socio-economic context, it is important to succeed in NbS appropriation by everybody to understand these interactions.
- testing "on farm" devices for monitoring the input required by the soil-water balance equation or the soil water content under these practices
- study of NbS at field scale and their effects on water on different climatic and pedologic conditions -> the main objective would be to objectify water savings under these different practices.

Agricultural engineering research topics should address:

- improve precision agriculture techniques to optimize cover crop termination date depending on weather conditions and main crop response (i.e., indicators of water stress)
- adapt techniques to make NbS easier for farmer to apply

Needs and ideas for Operational Groups (OG)

Different kinds of OG can be imagined. In a technical part we can suggest:

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- Farmer using straw in tracks between onion beds to reduce run-off. Small-scale test was successful but how to upscale?
- How to quantify water savings through soil and crop management practice?

There is a lot of common preconceptions on NbS and water. The objective of this OG would be to define methodology to quantify water savings. The main activities could be a farmer network of diverse NbS. Different measures would be done on site to look at method relevance. OG group should provide to farmer a guide to estimate water savings according to each NbS. The potential partners would be farmers, researchers.

- NbS for water management in mountain agricultural areas

The objective of this OG would be about feasibility of NbS in mountain agricultural areas. Results could be advices to succeed in doing NbS. Potential partners are farmers, researchers, managers of natural areas, state structure. The main activities would be trials of different NbS.

- How to start and implement Conservation Agriculture (CA) practices. Elaborate good practice for transition from conventional to CA

One of the obstacle to transition to CA practices can be transition phase. It can be hard for a farmer to change all about his system without any clue. This OG could develop a guide about good practices for transition from conventional to CA. Potential partners could be farmers, Conservation Agriculture associations, researchers.

- Finding alternatives to glyphosate for CA

The main criticism made to CA is glyphosate dependance. The objective of this OG would be to study if it is possible to build a CA system without glyphosate. This OG could test different alternatives and study resilience of these different systems. Results could be advices to reduce glyphosate dependence.

If we speak more about social:

- Assessing the benefits of using NbS at farm level

To promote NbS, it is important to explain all the benefits of using NbS and to have a multi-criteria approach. The objective of this OG could be to propose multiple indicators to compare different systems. Potential partners are farmers, researchers, sociologist, state structure.

- Testing model of NbS management
- How to manage transition phase to NbS?

Transition phase is one of the main obstacles about NbS. This OG would work on different levers that could help farmers in this phase. Results could be leads to develop NbS. Potential partners are farmers, researchers, economist, sociologist, state structure.

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