Going from rain to gain: blue and green water management practices

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Going from rain to gain:
blue and green water management practices

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Abstract. For many decades, the irrigation sector has enjoyed a privileged situation being supplied with liberal volumes of subsidized water on a priority basis. The contemporary situation is quite different. The urban centres and their industrial-service sectors are now perceived as engines of economic growth and innovations. The question is: *"how to provide the growing urban centres with their water demands and combine the tremendous challenges to ensure food and environmental security?"* The answer to this question implies that our efforts should be directed to the management of both the blue and the green water. Indeed and for various reasons, in many countries effective conservation and use of rainwater are seldom seen as a water resource management task. The conventional conceptualisation has neglected a large unnoticed resource: the green water source, i.e. the infiltrated rain in soil that supports all plant production, including rainfed agriculture. On the contrary, current institutional and technological responses are mostly focussing on the blue water and surface water in particular, which is indeed only a small part of precipitation. Even though countries must continue to improve management of blue water, the path of making better use of green water should be fully explored. A better use of green water – as a substitute for further pressure on blue water - is thus a win-win governance option. Green water can yield positive returns in crop production beside its potential of freeing up blue water that can be used for non-agricultural economic activities as well as for maintaining required stream flows to sustain the aquatic ecosystem. To govern water from rain to gain, focus should be on more efficient use of rainwater through integrated land and water resources management, conservation farming, watershed management and rainwater harvesting.

Keywords. Rain – Green water – Blue water – Management – Rainwater harvesting.

Valorisation des eaux de pluie par la gestion de « l'eau verte » et de « l'eau bleue »

Résumé. *Pendant des décennies, le secteur de l'irrigation a eu le privilège de disposer de volumes d'eau importants sous des formes subventionnées. Actuellement, la situation a beaucoup changé. Les centres urbains et les secteurs des services et de l'industrie sont devenus des moteurs de croissance économique et d'innovations. "Comment satisfaire les besoins en eau croissants des centres urbains tout en tenant compte des défis énormes pour assurer la sécurité alimentaire et environnementale?" La réponse à une telle question doit être recherchée dans la gestion intégrée de l'eau verte et de l'eau bleue. En réalité, et pour différentes raisons, en de nombreux pays la conservation et l'exploitation efficace des eaux de pluie sont rarement considérées comme des tâches qui entrent dans la gestion des ressources en eau. La conceptualisation conventionnelle a négligé une grande ressource inaperçue: l'eau verte, à savoir, l'eau de pluie qui s'infiltre dans le sol et qui est à la base de toute production végétale et de l'agriculture pluviale aussi. Au contraire, les politiques et les technologies actuelles sont focalisées surtout sur l'eau bleue, et l'eau de surface en particulier. Etant bien entendu qu'il faut poursuivre une meilleure gestion de l'eau bleue, il faudrait explorer pleinement le chemin de l'eau verte. Une meilleure utilisation de celle-ci – servant à alléger la forte pression exercée sur l'eau bleue – est une option de gouvernance gagnante-gagnante. L'eau verte peut engendrer une rentabilité intéressante au niveau de la production des cultures, et soulager l'eau bleue d'une quantité qui serait ainsi utilisée pour des activités économiques non agricoles et pour le maintien du débit minimal nécessaire pour l'écosystème aquatique. Pour la valorisation des eaux pluviales il faudrait assurer une exploitation plus efficace à travers la gestion intégrée des terres et des ressources en eau, la culture de conservation, l'aménagement des bassins versants et la récupération des eaux de pluie.*

Mots-clés. *Pluie – Eau verte – Eau bleue – Gestion – Récupération des eaux de pluie.*

I – Introduction

Nowadays, in many river basin, the water resources are already close to or already over-committed in the sense that the stream-flows have been depleted beyond what is needed for flushing, dilution and sustaining aquatic eco-systems. Such over-commitment has already spread over 15% of the land area hosting 1.4 billion inhabitants those are already suffering the water shortages (Smakthin *et al.*, 2004). Under such situation, one consequence is that further expansion of irrigated agriculture can only be very limited which makes the food security an alarming issue. Indeed, food needs are increasing and food consumption is moving towards more water-intensive items.

Today, consumption drives food production which is changing the consumptive use of water and impacting already stressed water resources, eco-systems and the water available for other societal uses. However, food production will always be highly water consuming from both the green and blue-water perspectives. Therefore, for arid and semi-arid regions, where rain-fed smallholders farming dominates agriculture, it is needed a new agricultural revolution calling for harvesting the potential of green-water in the soil through conservation farming and rainwater harvesting. Equally, water harvesting has to shift its focus from the blue-water and incorporate, also, green-water linked to land use and see rainfall as the manageable freshwater resource.

The blue and green water of the continental global precipitation, some 65% forms green-water in the soil (soil moisture) to be consumed in biomass production by forests, grasslands, wetlands and crop lands. The remaining 35% generates blue-water (surface and groundwater), i.e., the water that is available in rivers, lakes and aquifers out of which only 10% is withdrawn to meet societal needs for settlements, industry, irrigation and hydropower (Fig.1).

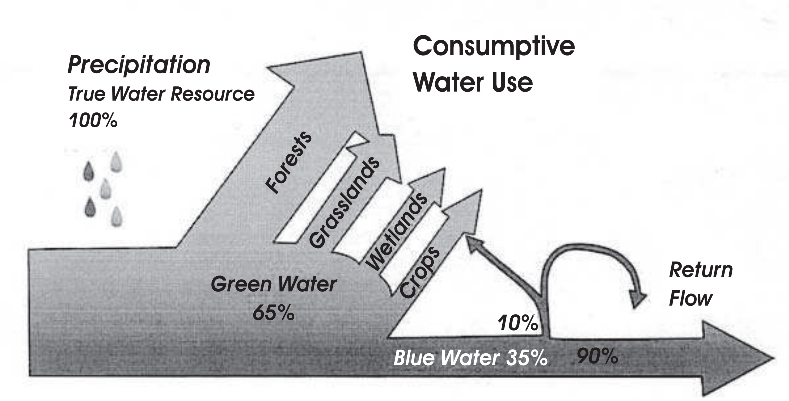

Figure 1. Green and Blue Water.

Discussions concerning food production and food security have invariably focused on the blue-water resources, while the significantly larger green-water resources, i.e. the water invisible to the naked eye, is overlooked.

The long standing emphasis on irrigated agriculture has largely had the side-effect of neglecting potential and substantial improvements of the productivity of rain-fed agriculture.

With blue-water resources, already heavily over-reported in many parts of the world, it is time to revisit and revitalise green-water based food production. This is most obvious in the Middle East and North Africa regions. Indeed, those regions ran out of water for food self sufficiency already in the 1970s (Allan, 2002). For arid and semi-arid countries, using the green-water more productively within rain-fed agriculture, can have, on one hand, yield positive returns in crop production and, on the other hand, increase the potential of freeing-up blue-water that can be used to meet the increasingly water demands in the other sectorial water uses as well as maintaining required stream-flows to sustain aquatic eco-systems.

II – Green-water management: the challenge

Today there are several driving forces pushing towards up-grading the green-water management, among those the following:

- intensified blue-water competition

During the last century, the rate of withdrawals of blue water resources was about 2-2.5 times more rapid than overall population increase (Fig. 2).

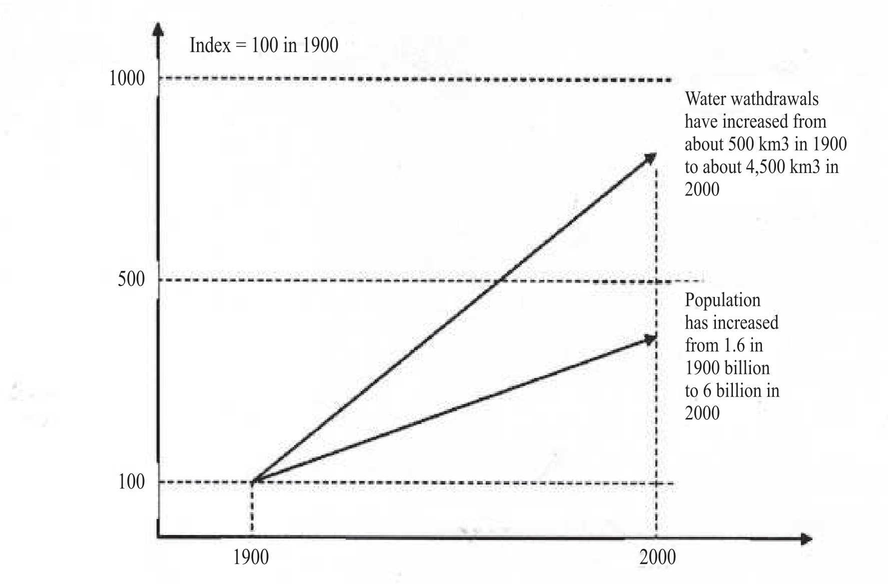

Figure 2. Rate of water withdrawals and demographic change in previous century.

Water withdrawals have increased from about 500 km^3 in 1,900 to about 4,500 km^3 in 2.000. This means that it is primarily the water in rivers, lakes and aquifers, referred as “blue-water” that has been exploited. The demonstrated figure indicates clearly that an extrapolation in the withdrawal of water is neither possible nor desirable whereas the demographic curve will continue to grow and by 2050 a most likely scenario is that another two billion people will be added to the world’s population. The fact that the available water is more or less constant overtime, the competition and conflicts among the sectorial water uses has naturally increased and it will continue to increase.

No doubt the water situation under such notable demographic increase is alarming in many countries of the world and the situation is also worsening in some respects in terms of water management and water quality. The question is: *“how can the increased competition be handled and how to avoid the increasing tensions and conflicts between water users?”*. The direct answer could be through improving water productivity in both irrigated and rain-fed agriculture, following an appropriate integrated land and water resources management approach for the two agriculture systems (Hamdy, 2008).

III – Rainfall partitioning and its losses in farming systems

One of the crucial questions to be clearly identified is: *"where does the rainwater go?".*

In arid and semi-arid regions, a large proportion of the arable land are subjected to shortages in available water, recurrent dry spells, as well as recurrent periods of drought during crop growth, those are harmfully reducing the yield production.

In such areas, the majority of land users depends on rainfall for their livelihood, i.e. green water not on irrigation based on blue water. However, for arid and semi-arid regions, rainfall is highly erratic and most rainfalls as intensive, often convective storms with very high rainfall intensity and extreme spatial and temporal rainfall variability. In fact, in such regions, the poor distribution of rainfall overtime often constitutes a more common cause for crop failure than absolute water scarcity due to low cumulative annual rainfall.

Figure (3) gives an indication of the partitioning of rainfall into different water flow components in rain-fed agriculture in semi-arid zones of Sub-Sahara Africa.

Soil evaporation accounts for 30 to 50% of rainfall (Cooper *et al.*, 1987; Wallace, 1991; Rockstorm, 1997) a value that can exceed 50% in sparsely cropped farming systems in semi-arid regions (Allen, 1990).

Surface runoff is reported to account for 10 to 25% of rainfall (Casenave and Valentin, 1992; Penning de Vries and Ditèye, 1991). The characteristics in dry lands of frequent, large and intensive rainfall event result in significant drainage, amounting to some 10-30% of rainfall (Klaji and Vachaud, 1992).

The results is that productive green water flows as transpiration, in general, is reported to account for merely 15-30% of rainfall (Wallace, J. pers. comm.). The rest between 70-85% of rainfall is lost from the cropping system as a non-productive green water flow, as soil evaporation and as blue water flow (deep percolation and surface runoff).

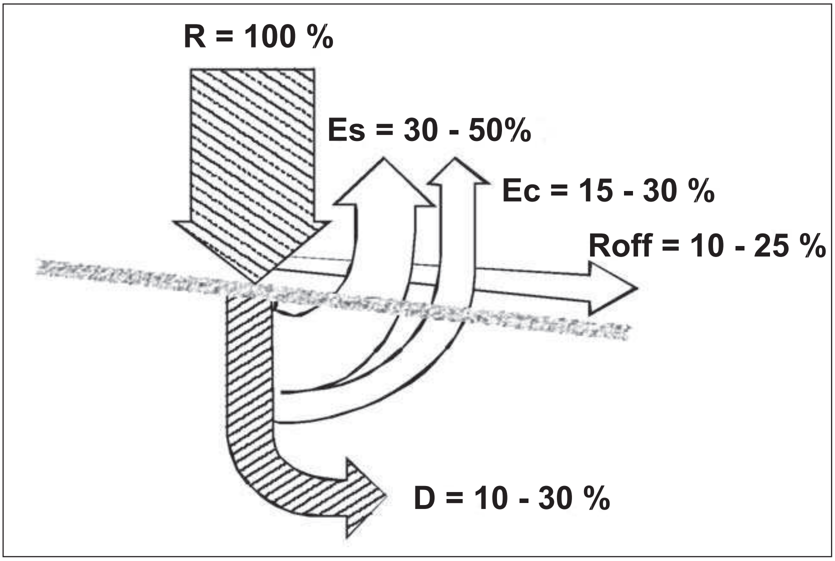

Figure 3. General overview of rainfall partitioning in farming systems in the semi-arid of sub-Saharan Africa. R = rainfall, Ec = plant transpiration, Es = evaporation from soil and through interception, Roff = surface runoff, D = deep percolation.

As shown in Fig. (3), it is quite apparent that there is a high risk of soil water scarcity in crop production irrespective of spatial and temporal rainfall variability. Rainfall varies from 400-600 mm in semi-arid zone and has an approximate range of 200-1000 mm from the dry semi-arid to the dry sub-humid zone. The productive green water flow component returned to the atmosphere as transpiration, being with values accounting to only 15-30% of rainfall means that over 2/3 of the rainfall is lost. This lost water and its conversion from evaporation to transpiration would be sufficient to produce 4-5 reasonable crop yields, assuming roughly 100 mm of transpiration flow for a grain yield of 700 - 1000 $kgha^{-1}$ if the totality was allocated as plant transpiration.

IV – From rain to gain: effective conservation and use of rains

Blue water is only a small part of the precipitation that falls over a country. For various reasons, an effective conservation and use of rains is seldom seen as a water resource management task. One reason is probably that it is much more easy, although quite expensive, to exploit blue water resources.

Another more interesting explanation is that green water management, i.e. harvesting the rains and better use of the water that is stored as soil moisture, requires an integration and land/soil and water management. In rainfed agriculture the potential to better utilize the green water resource must be explored. There is a large potential to upgrade rainfed agriculture in arid and semi-arid regions (SIWI *et al.*, 2005). It has been shown that just by meeting the soil and plant deficiency challenges, crop yields may be doubled or even tripled (Rockstrom, 2003).

It is therefore fundamental to realize that in such zones the crop production potential is considerable. For this purpose, the water-related problematic, typical for arid and semi-arid zones, has to be properly understood. The situation in those areas could be characterized in terms of four challenges that have to coped with (Falkenmark and Rockstorm, 2004):

- long dry period and a wet season interrupted by dry spells (green water challenge)
- infiltration problems linked to crust forming soils (green water challenge)
- low run off production, leaving small water courses empty, except during heavy rains (blue water challenges)
- recurrent drought years (both green and blue water challenges
- measures and management practices for improving rain water use.

The green water production potentials have yet to catch the eyes of most water managers and have only marginally been subject to legislative measures or other types of political and managerial responses. In the meantime, there is currently increasing focus linked to conservation farming, watershed management and rain water harvesting in rural areas. Studies in India by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) showed that increased productivity in rainfed agriculture was largely due to reduced run-off and increased rainwater use efficiency (65 per cent). In addition, it has been shown that conservation farming can lead to improved plant production through decreased run-off as well as improving groundwater recharge. Moreover, the integrated watershed management programme showed a potential of doubling the productivity on farmers' fields in rainfed areas while sustaining the natural resource base (Wani *et al.*, 2003).

These findings show that improved rainfed agriculture can involve many environmental and economic gains that have the potential to be sustained in the long run, that is: going from rain to gain. It is also of interest to indicate that such studies demonstrated clearly the interface between blue water and green water that measures of improving rainwater use has positive impacts on ground water recharge and irrigated agriculture.

Regarding green water management, it is well recognised that not all the management practices applied to blue water are relevant to green water. For example, the application of various pricing regimes will be ineffective since the green water is coming from the rain which falls directly onto the land. It is basically the size of land and soil characteristics that determine the availability of green water and, therefore, it is irrelevant to use economic incentives for allocating water.

For the green water economic incentives can be in the form of micro-credit schemes for introducing new soil/water management technologies such as rainwater harvesting and supplementary irrigation to protect the growing crops against prolonged periods of drought. In our opinion, to improve the use of green water focusing should be on integrated approaches and strong focus must be put on local processes of participatory approaches, decentralization and national legislations and institutions that can facilitate inclusiveness and access to the needed tools to improve the use of green water to achieve the most possible gain from each drop of rain. In addition, major emphasis should be given to the water and land/soil interface due to its critical impact on improving the use of green water for increased food production. Indeed, a land use decision is also a water decision since land use changes can influence the partitioning of the rainfall, beside it will also affect various components of the hydrological cycle such as runoff, infiltration and evapotranspiration.

From an administrative point of view, land and water are normally separated. Within the water sector, the concept of integrated water resources management (IWRM) is well established, even though its implementation, in practice, has been difficult. There is a need to integrate land and water resources issues. This has been captured by Duda (2003) who in the context of fragmented environmentally related international conventions proposes that the proper terminology should be "*integrated land and water resources management" (ILWRM)*. This means that governance responses to green water will need to shift the focus from blue water allocation to more efficient use of rainwater and intensify the integration of water and land/soil management.

V – Getting the most out of blue water availability: needed research

In arid and semi-arid zones, the main challenge should be: *how to increase green water productivity making the most of green water availability, i.e. the soil moisture.* The production potential is large, provided that plant productivity problems, due to dry spells, etc., can be alleviated by soil/water management measures (green water problems). Affordable small scale technologies and approaches that farmers' capacities could assimilate hold tremendous promise in getting the most out of the falling rains.

Governance and technologies responses should be directed towards making better use of the green water in rainfed agriculture; even though focus should shift from blue water allocation to more efficient use of rainwater, such as through conservation farming and watershed management.

Technically and politically, major efforts are nowadays directed to the improvement of rainfed agriculture. It is well recognised that achieving food security in developing countries of arid and semi-arid regions implies better use and management of both green water and blue water. Improving the rainfed agriculture and increasing the availability of green water (soil moisture) is fundamentally depending on the different approaches we are already implementing in the collection of the falling rains with maximum reduction in water losses which are extremely high lying between 70 to 85% of the total rainfall. In this regard, rainwater harvesting technique is the one widely practiced in most arid and semi-arid zones.

VI – Rainwater Harvesting

Water harvesting may be the most pertinent entry point to farming systems improvements in water scarce regions. The reason for this is the reduced risks for crop failures due to dry spells, which in turn will increase the willing among farm entrepreneurs to invest in other inputs.

However, albite the vast knowledge and experience accumulated in the field of water harvesting, there are still large gaps in research that need to be filled. Fields identified as primary constraints for the successful transfer or innovation and technologies are within the socio-economic domain and relate to the flexibility of concepts introduced so as to fit into the social context. Often lack of education, is a primary constraint, but, sometimes, the proper understanding of underlying social factors can make a difference between a success or failure in introduction/implementation of water harvesting systems.

Research is also needed regarding technical solutions, taking into account the catchment requirements and dynamics as well as the design of the system as such. The main issue is to reduce water losses by evaporation and seepage.

At present, very little is known on socio-economic, environmental and hydrological impact of up-scaling small-scale water harvesting technologies. This requires understanding of complex biophysical processes at different time and spatial scales, as well as inter-sectoral dynamics between, for example, processes in the agro-ecosystem and driving forces behind human land-use decisions. Furthermore, this understanding has to span over a broad scale spectrum from the farm level to the river basin scale, in order to anticipate impacts between upstream and downstream water uses and users.

VII – Conservation tillage: need for systems research

Conservation tillage (CT) may be the most interesting water harvesting option available in order to achieve quick improvements in rainfall partitioning and crop yield on a large scale. Indeed, CT focuses on maximizing infiltration and the improvement of soil productivity by abandoning the inversion of the soil through conventional ploughing.

However, it could be argued that the low adoption of CT among small-holder farmers may be linked to the lack of systems research, studying all the components: tillage, timing, livestock management, fertilization, soil conditions, farm management, etc., which together from the basis of a successful conservation tillage system. There is research gap on system oriented adaptive on-farm research on the design, functioning, bio-physical criteria and implication of CT-production systems.

VIII – Dry spell occurrence and mitigation

This issue should deserve further research as the manageable challenge for the farmer is to mitigate the effects of dry spells which occurs frequently in semi-arid farming systems.

There is very little research carried out studying the occurrence of dry spells from a management perspective, and the potential of planning for dry spells mitigation using water harvesting. Planning tools have to be developed from fundamental science that enables the assessment of water requirements to mitigate dry spells and the potential of harvesting required water.

IX – To convert evaporation to transpiration

An interesting win-win option is to convert non-productive evaporation to productive transpiration.

However, from a water harvesting perspective, all the possibilities of using water harvesting as a method for improving the crop environment in favour of: (i) lower saturation deficit (VDP, Vapour Pressure Deficit) and (ii) increasing the T/ET ratio can be of large importance for the water availability on a watershed scale. The know-how on the ways water harvesting could contribute to lower VDP and higher T/ET is still limited. Research is required to study the actual potential of water harvesting to affect VDP, WUE_{ET}, WUE_{T} and T/ET ratio.

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