RAIN-FED AGRICULTURE IMPROVEMENT:
WATER MANAGEMENT IS THE KEY CHALLENGE

by

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Abstract

Rain-fed agriculture will continue to produce the bulk of the world's food. It is already practiced in 80% of the world physical agricultural area and generates 62% of the world's staple food (FAOSTAT 2005).

Estimates suggest that 75% of the increased water requirements needed to attain the 2015 hunger reduction target of the Millennium Development Goal (MDG), will have to come from water investments in rain-fed agriculture, those, unfortunately, that have been neglected over the past 50 years. In arid and semi-arid regions water management is the key challenge for improving food production in rain-fed agriculture due to the extreme variability of rainfall, long dry season and recurrent droughts, floods and dry spells. Water management should be directed towards the reduction of water-related risks posed by high rainfall variability rather than coping with an absolute lack of water.

However, to reduce these rainfall-related risks a new era of water investments and policy is required. Investments are needed in soil, crop and farm management in small holders' rain-fed farming systems, those to improve water productivity to add new freshwater with valuable water saving through local management of rainfall and runoff.

To achieve such goals there is an urgent need for widening policy scope to include new strategies for water management in rain-fed agriculture and to provide the required investments to implement the management options to build knowledge and to reform and develop institutions.

The focus in this paper will be on the current conditions for key water management challenges facing rain-fed agriculture from the perspective of water productivity and the water management spectrum to upgrade rain-fed farming systems.

Introduction

Some eighty percent of the world's agricultural land is rain-fed, contributing to at least sixty percent of global food production. It is out of discussion the very important role irrigation is playing in supplying foods, but for most countries facing an acute food gap, the potential for increasing water withdrawals for expanding irrigated area is quite limited. Therefore, for irrigated agriculture, increasing food production to fulfil the food gap is fundamentally depending on our capability in increasing crop water productivity to produce more biomass per unit of water already withdrawn for irrigation purpose (more crop per drop of irrigated water). This confirms that the greatest potential increase in yields are in rain-fed areas where many of the world’s poorest rural people live and where managing water is the key to such increase. The fact that nearly over 60% of the cereals production is provided in rain-fed agriculture give the evidence that the foreseeable future world food will be very difficult to achieve unless further efforts are directed to improve rain-fed agriculture from the perspective of water productivity and the water management spectrum to upgrade rain-fed farming system.

Nowadays, there is a growing understanding among water professionals that absolute water scarcity not necessarily is the factor limiting a doubling or even a quadrupling of food crop yield even in those arid and semi-arid countries suffering an increasingly water scarcity in their available water resources. On the other hand, it is to be clearly understood that water scarcity is the key factor in food security. However, in spite of such different views, the crucial question which is still seeking a reasonable answer is: *how rain-fed crops can be improved?* The answer can be found in the outcome of the later roundtable discussion in the Swedish Environmental Journal Ambio (March, 1998) that stressed the need for serious efforts to achieve sustainable increase in food production within a finite amount of rainfall if we are to stand any chance to meet the food security challenge of today. Such findings points at a very existing window of opportunity to improve water productivity, to increase food production as well as to raise up the livelihoods of rural communities through using innovative and appropriate water resources management techniques. Supplementary irrigation based on water harvested from local rain-water of flash floods is one of the most promising approaches for upgrading rain-fed agriculture. A significant gain in crop production in rain-fed agriculture will therefore have to come from small scale harvesting of water in combination with protective irrigation.

Development of protective irrigation has to involve not only the engineering measures but also a proper evaluation of the social factors surrounding a system and focus has to be put on the farmer’s reality. Equally, the way of thinking about water by water professionals and policy-makers should be changed realizing the need to improve the use not only of blue water in lakes, rivers and aquifers but, also, that of green water, the soil moisture under rain-fed agriculture which is still poorly managed.

Water use in rain-fed and irrigated agriculture

The main source of water is rainfall falling on the earth’s land surface (110,000 cubic kilometres) (Fig.1).

When atmospheric precipitation reaches the ground it divides into several sections which pursue the terrestrial part of the hydrological cycle along different paths. As presented in (Fig.1), adapted from Shiklmano (2000), FAO (2002), Ringers et al. (2003) and Rockstrom (1999), it is estimated that out of the total annual amount of precipitation (110 km3), about 40,000 km3 is converted into surface runoff and aquifer recharge (Blue Water) and an estimated 70,000 km3 is stored in the soil and later returns to the atmosphere through evaporation and plant transpiration (Green Water).

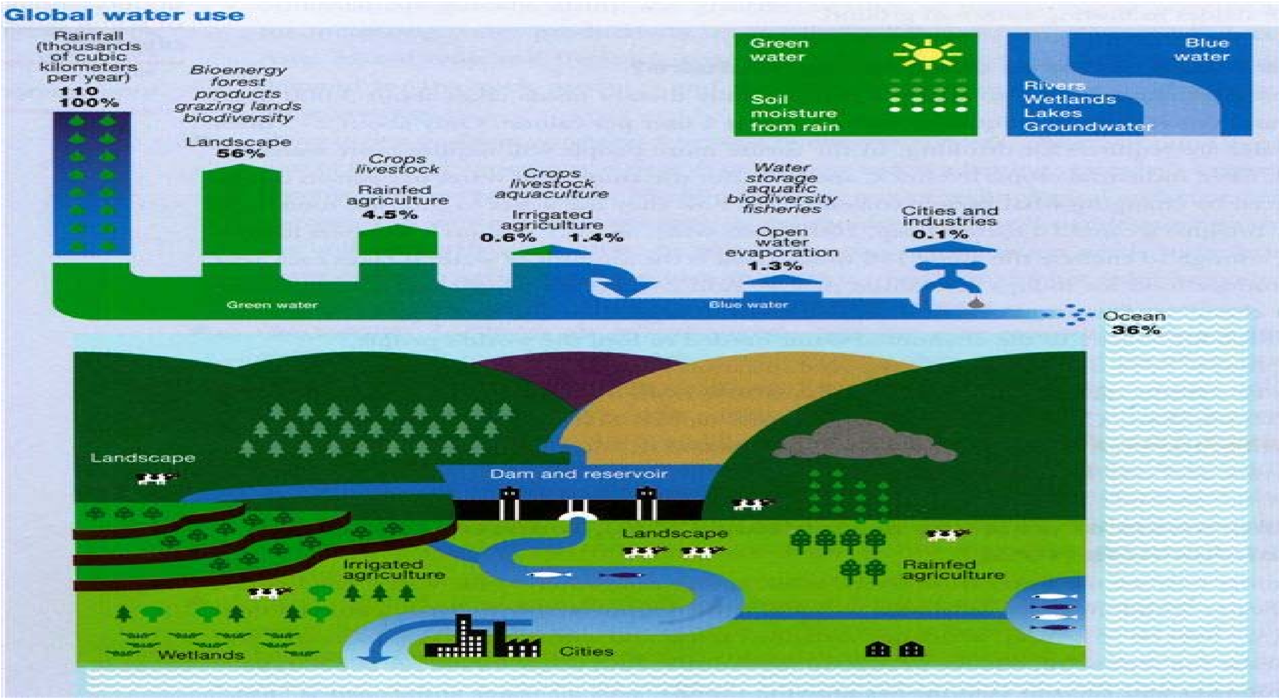


Fig. 1 – Water use in rain-fed and irrigated agriculture. Source: Comprehensive assessment of water management in agriculture. 2007, Water for Food, Water for Life - (eds) D. Molden

A schematic of the hydrologic cycle components (Fig.2) illustrates where and how renewable annual water flows move through the hydrological cycle.

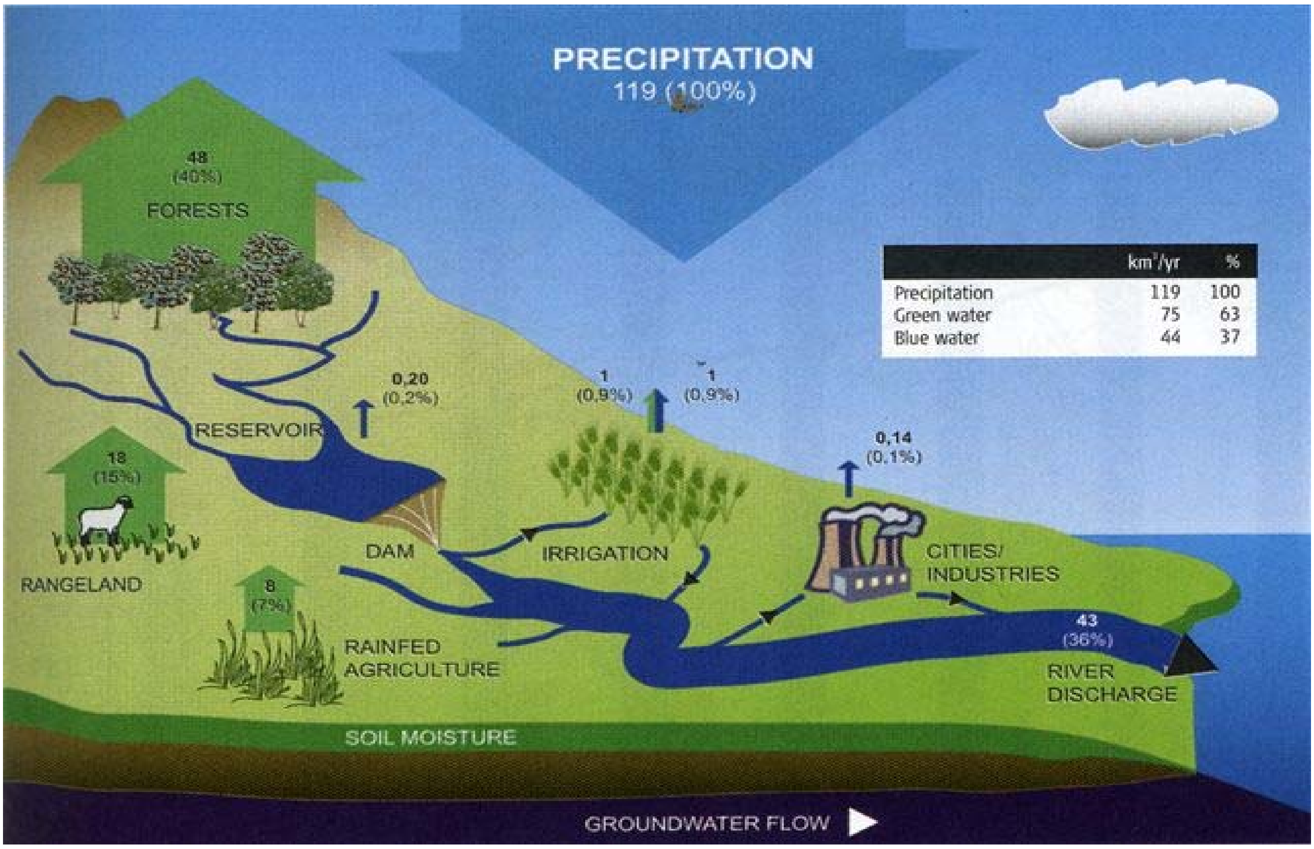
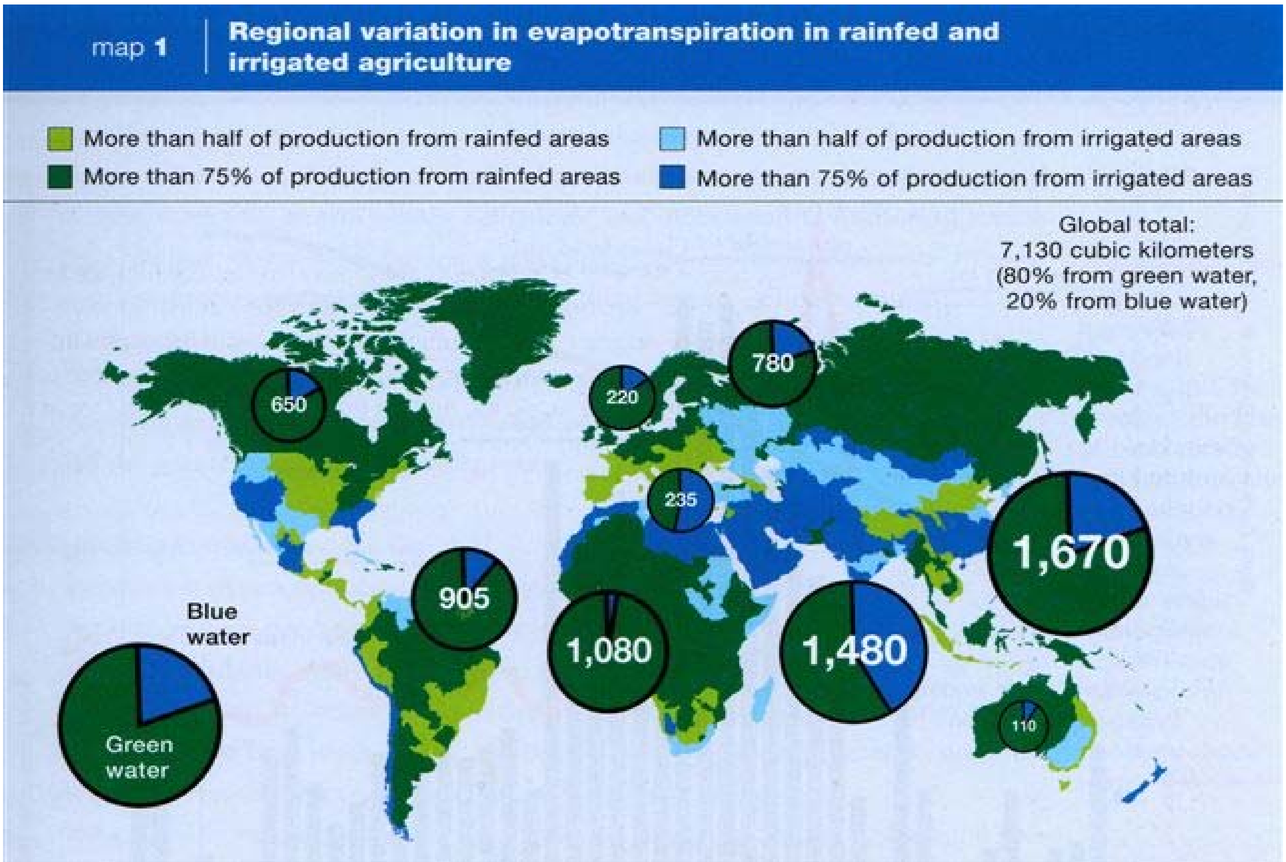


Fig. 2 – Blue and Green Water. In: Water a Shared Responsibility. The United Nations :World Water Development Report (2) – 2006. FAO, IFAD.

Blue water is the freshwater that sustains aquatic ecosystem in rivers and lacks. It is used for drinking or domestic purposes, to industry and hydropower and to irrigated agriculture where nearly around 70% of this water source is used. Indeed, irrigation uses in addition to blue water the green water, where as rain-fed agriculture uses only green water. The green water/blue water concept has proven to be useful in providing a more comprehensive vision of the issues related to water management, particularly in the agriculture sector (Ringersma et al. 2003).

Comprehensive assessment of water management in agriculture (2007) estimates that crop production takes up 13 percent (9,000 km3 per year) of the green water delivered to soil by precipitation, the remaining 87 percent being used by the non-domesticated vegetal world, including forests and range land. Blue water withdrawals are about 9% of the total blue water sources (43,800 km3) with 70% of withdrawals going to irrigation (2,700 km3).

Globally, about 80% of agricultural evapotranspiration is directly from green water with the rest from blue water sources (Map. 1)



Source: Water for Food, Water for Life: a comprehensive assessment of water management in agriculture. (Earthcan, 2007).

Total evapotranspiration by irrigated agriculture is about 2,200 km3 (2% of rain) of which 650 km3 are directly from rain (green water) and the remainder from irrigation water (blue water).

Upgrading rain-fed agriculture and future food demands

According to FAO (2005) projections food demand in 2030 is expected to be 55 percent higher than 1998. To respond to this demand, global food production should increase at an annual rate of 1.4 percent.

At present, 55% of the gross value of food is produced under rain-fed conditions on nearly 72% of the world's harvested crop land. The subject receiving intense debate is the future food demands whether it will be provided by rain-fed or irrigated agriculture. Indeed, in the past many countries focused their water attention and resources on irrigation development to fulfil both present as well as future food production gaps.

However, what should be clearly understood is that most of the world's food production does not rely on freshwater withdrawals at all and does not necessarily accelerate the naturally occurring rates of evapotranspiration. This evidently means that the bulk of the world's agriculture production is rain-fed not irrigated.

At the global level, it is well recognised that the potential of rain-fed agriculture is large enough to meet present and future food demand through increased productivity. In this regard, an important option is to upgrade rain-fed agriculture through better water, soil and land management practices. This can be done through several ways, including the following diverse options (Fig. 3):

- increasing productivity in rain-fed areas through enhanced management of soil moisture and supplemental irrigation where small water storage is feasible;
- improving soil fertility management including the reversal of land degradation, and
- expanding cropped areas

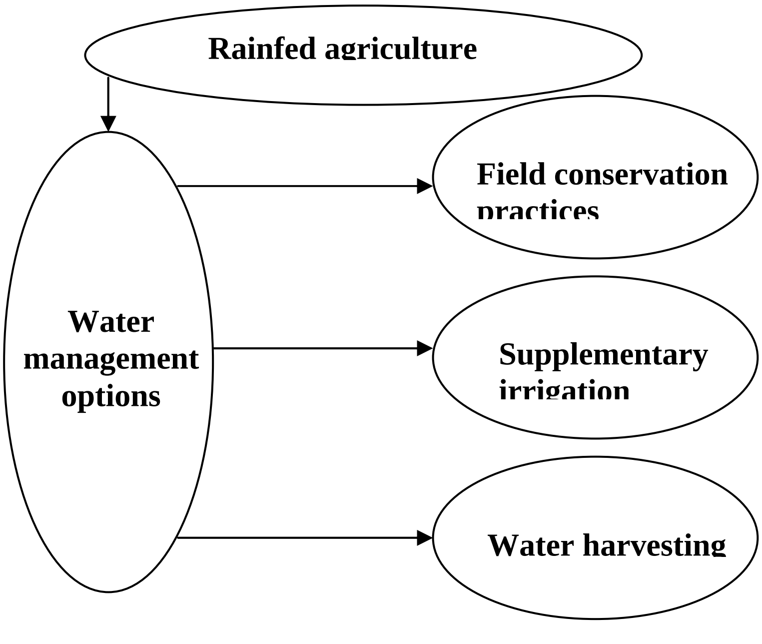


Fig. 3 – Diverse options for water management in rain-fed conditions

However, upgrading rain-fed agriculture to meet the increasingly demand on food is not an easy process but a rather complex one. Changes are needed in land, water and crop management under rain-fed agriculture. But to support these changes, investments are required to build knowledge and to reform and develop institutions. A combination of investments, policy and research approaches will clearly be needed. Indeed, lack of commitment and targeted investment, insufficient human capacity, infective institutions and poor governance are the major obstacles behind the low adoption rates of improved technologies as well as in not materializing rain-fed yield improvements.

Upgrading rain-fed agriculture: required water investments

Looking for food security for all, two major water realities are existing**.** *The first,* is that rain-fed agriculture will continue to produce the bulk of the world's food. *The second,* concerning the water productivity which is very low in rain-fed agriculture, thus, providing significant opportunities for producing more food with less freshwater. Both realities are strongly connected to each other, hence, increasing the crop water productivity in rain-fed agriculture is the solely effective pathway towards attaining food security. A key to success is to invest in the often untapped potential of upgrading rain-fed agriculture through integrated water investments. The key challenge is to reduce water related risks posed by high rainfall variability rather than coping with an absolute lack of water. In rain-fed farming, there is generally enough rainfall to double and, even, to quadruple yields but such rainfall is available at the wrong time causing dry spells and much of it is lost. The temporal and spatial variability of climate, especially rainfall, is a major constraint to yield improvements, competitiveness and commercialisation of rain-fed crops, tree crops as well as livestock systems in most of the tropics. This is why investment in soil, crop and water management is crucial for upgrading rain-fed agriculture.

However, reducing the rainfall related risks cannot be achieved in the absence of the needed investments in water management as they are the entry point to unlock the potential in rain-fed agriculture.

Improving rainwater management

Evidence from water balance analyses on farmers' fields around the world shows that only a small fraction of rainfall, generally, less than 30%, is used as productive green water flow (plant transpiration) supporting plant growth (Rockstrom, 2003). Rainfall partitioning in the semi-arid tropics indicating rainfall losses from the farm scale is given in (Fig. 4).

The presented data show that losses in rainfall through drainage, surface runoff and non-productive evaporation is extremely high (70 up to 85 percent), where as the part of the rainfall used productively, to produce food is of minimum values lying between 15% up to 30%. In arid areas, only as little as 10% of rainfall is consumed as productive green water flow with most of the remainder going to non-productive evaporation flow (Oweis and Hachum, 2001).

Those prevailing conditions imply that investments should be directed for the improvement of rainwater management which is truly poor generating excessive runoff, causing soil erosion and poor yields due to a shortage of soil moisture. Investments in this area will not only maximize rainfall infiltration and the water-holding capacity of the soils, but, in the meantime, will minimize land degradation as well as increasing the water available in the soil for crop growth. The potential gains from water investments to meliorate rainwater management in rain-fed agriculture will be not only through achieving significant and sustainable increase in food production, but, equally, by improving environmental sustainability.

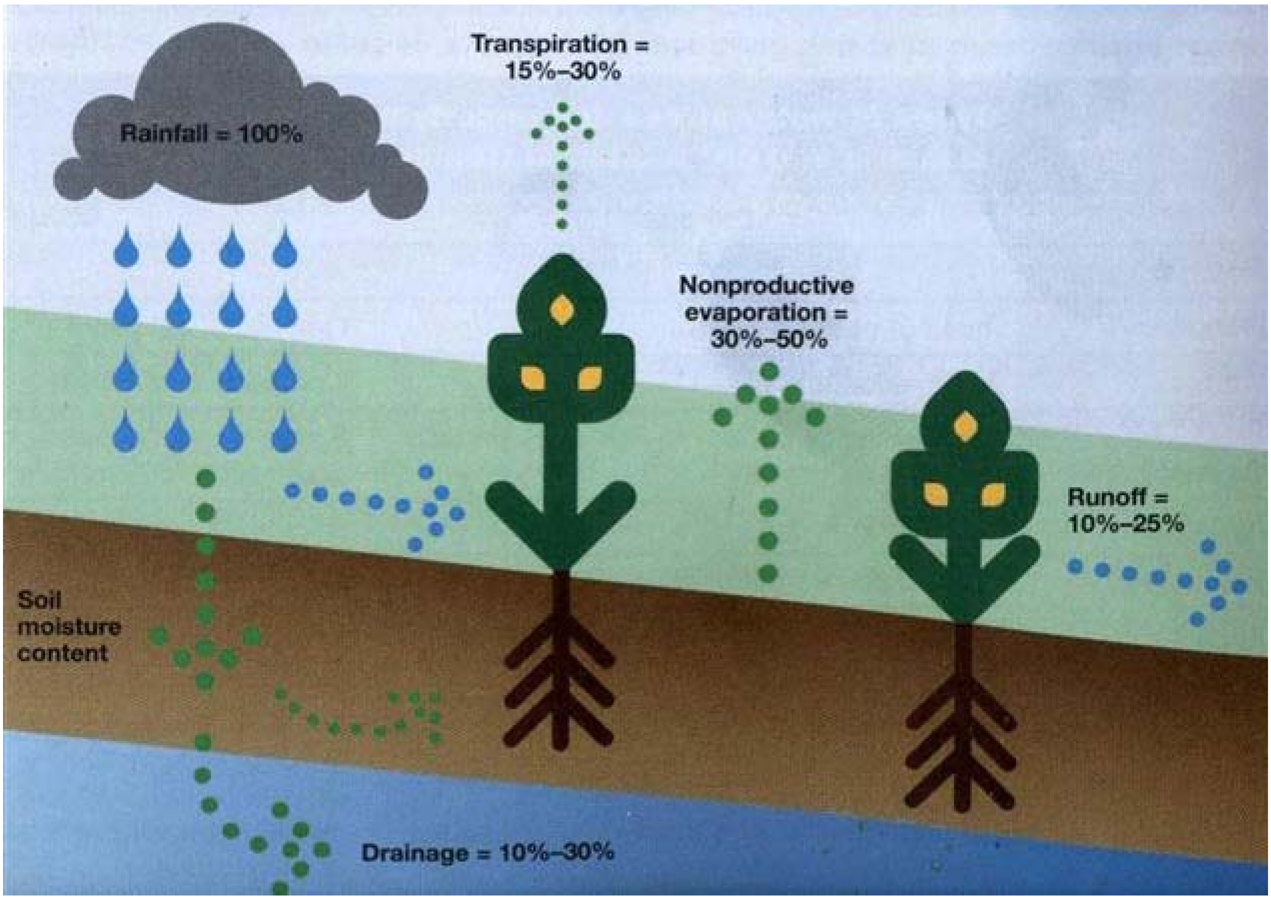


Fig. 4 : Rainfall partitioning in the semiarid tropics. Source: Water for Life, Water for Food: a comprehensive assessment of water management in agriculture (2007) (ed) D. Molden.

The global analysis of more than 100 agricultural development projects, Pretty and Hine (2001) found that in projects that focused on improving rain-fed agriculture, yields doubled on average and often increased several hundred percent. This clearly demonstrates and emphasizes again the large potential for investments in upgrading rain-fed agriculture.

However, what to be stressed here is that the investments required today differ greatly from those in the last half century. They will have to increase human and institutional capacity and improve management and infrastructure. Investments should be more strategic, planned within the overall national framework regarding the rain-fed agriculture upgrading.

Water management to upgrade rain-fed agriculture

Water management to upgrade rain-fed agriculture encompasses a wide spectrum from water conservation practices for improving rainwater management on the farmers' field to managing runoff water (surface and sub-surfaces) for supplying supplemental irrigation water to rain-fed food production (Fig. 3).

Improving water management in rain-fed agriculture is a long term process and requires learning by doing using an adaptive approach. Such adaptive management approach should be responsive to the variability within systems as well as to the long term and slow ones changes. In addition, the management approach should carefully consider the increasing rainfall variability and frequency of extreme events such as drought, floods and hurricanes due to the emerging climatic changes. Recent studies (Fisher et al., 2002) of rain-fed cereal potential under different climate change scenarios estimated losses to be at 10% -20% of production area with some 1-3 billion people possibly affected in 2080.

Upgrading rain-fed agriculture: the constraints

The point which is under continuous bargaining by both politicians and professionals is mainly related to the simple question: *why water management investments in rain-fed agriculture have been neglected over the past 50 years in spite of the well stated fact that, at present, rain-fed agriculture dominates world food production and it will continue to produce the bulk of the world's food?* There are several reasons resulted in such situation. However, to answer this question we have to return back with our memory to the few past years where all the efforts were directed to the development and management of the blue water with a major focus on developing and allocation of such water particularly to large scale irrigation, expanding the irrigated areas and, thereby, increasing food production. Furthermore, large investments have historically tended to go to high potential irrigated areas, keeping most rain-fed areas with very poor infrastructure facilities.

In addition to such reasons, a primary reason, behind the lack of focus on water resources management in rain-fed agriculture, is the complete failure in establishing the enabling conditions needed to promote and upgrade rain-fed water management. This is demonstrated, on one hand, by the limited capacity of local institutions engaged in agriculture development and extension and, on the other one, by the very weak existing information systems.

On the globe, the know-how for better management of rainwater exists, but investments needed for turning this knowledge into innovations in governance, policy, institutions, practices and technologies are still very limited and, in many cases, are completely absent.

Rainwater management strategies and options

The work done by Critchley and Siegert (1991) indicated several rainwater management strategies to improve crop yields and green water productivity. One of these strategies is aiming at maximizing plant water availability in the root zone.

This implies three rainwater management strategies: two of them (A) and (B) are dealing with water harvesting and the third one (C) is on evaporation management:

(A) Water harvesting strategies: external water harvesting systems

Under this strategy there are several management options to be practiced using several tools including surface micro-dams, subsurface tanks, farm ponds, percolation dams and tanks as well as diversion and recharging structure. Harvested water within such tools are to be used for upgrading rain-fed agriculture through mitigating dry spells, recharging groundwater, enabling off season irrigation and facilitating multiple uses of water.

(B) In situ water harvesting systems, soil and water conservation

Such strategy in basically aiming to concentrate rainfall through runoff to cropped area or other use and to maximize rainfall infiltration. To put this strategy in action there are several management options which are technically simple and economically sounding and, therefore, they have wide use by farmers in many arid and semi-arid regions to capture and reduce losses in rainfall.

For instance, to maximize rainfall infiltration, this can be effectively achieved through terracing, contour cultivation, conservation agriculture and staggered trenches. On the other hand, bunds, ridges, micro-strips, broad-beds and furrows are the management options to capture and concentrate rainfall. Since, in situ, rainwater management strategies are often relatively cheap and can be applied on any piece of land, they should be optimised before water from external sources is considered. Therefore, soil and water conservation or in situ, water harvesting systems should be considered the logical entry-point for improved water management in rain-fed agriculture (Wani et al., 2003).

The analysis of both management strategies and options, it is quite evident that water harvesting include the following three components: a watershed area to produce runoff; a storage facility (soil profile, surface reservoirs or groundwater aquifers) and a target area for beneficial use of the harvested water (agriculture or other purposes). In addition, it indicates also that both strategies varies depending on the spatial scale of runoff collection, from in-situ practices managing rain on farm land (water conservation – the B strategy) to external systems collecting runoff from watershed outside the cultivated area –the A strategy). Both presented strategies are, indeed, storage ones from direct runoff concentration in the soil A-strategy to collection and storage of water in structures (surface, sub-surface tanks and small dams), -the B strategy.

(C) – Evaporation management strategy

The main purpose of this strategy is to reduce non-productive evaporation. This is a key window for improving green water productivity through shifting non-productive evaporation to productive transpiration. Keeping in mind that in semi-arid areas up to half the rainwater falling on agricultural land is lost as non-productive evaporation, this strategy of vapour shift of the evaporative loss into useful transpiration by plants is a particular opportunity to upgrade rain-fed agriculture in arid, semi-arid and dry sub-humid regions.

Research findings (Rockstrom, 2003; Oweis et al. 1998) indicated that large opportunities for improving water productivity are found in low yielding farming systems, particularly in rain-fed agriculture.

There seems to be ample room for improvements in water productivity through rainwater management. In rain-fed system evidence shows that the adoption of in-situ (micro-catchment) water harvesting for rainfall infiltration and that with supplemental irrigation for dry spell mitigation can raise twice the productive transpiration.

Reducing non-productive evaporation means more water available in the root zone that could lead to an increase in food production and thereby a simultaneous increase in water productivity.

Upgrading rain-fed agriculture: water management perspectives

Technically and politically it is well recognised that upgrading rain-fed agriculture is the future challenge to achieve both food security and water security. On the globe, the evidence of rain-fed agriculture conveys two key messages: ***the first***, emphasizes the major important role rain-fed agriculture could play in global food security and sustainable economic growth; ***the second*** message is that there are large opportunities for gains from new investments in water management. Experiences gained and lessons learned from many arid and semi-arid regions around the world, where rain-fed agriculture is the dominant producer for cereal crops, highlighted that investments in rain-fed agriculture have large payoffs in yield improvements and poverty alleviation through income generation and environmental sustainability.

However, up till now, due to the fact that major efforts were directed to irrigation water management without putting enough emphasis on water management in rain-fed agriculture, there are contrary views considering the rain-fed agriculture as a risky business with current yield production generally less than half of those in irrigated systems.

This is the key challenge rain-fed agriculture is facing as it is still lacking the appropriate policies and strategies to be implemented minimizing the risk and upgrading the rain-fed systems. Indeed, rain-fed agriculture has suffered from insufficient policy and institutional support for improving water management for production. In addition, the focus on blue water has led to week policies for water management investments in rain-fed agriculture.

Recently, management of green water resources and other investments to upgrade rain-fed agriculture have begun to receive increased priorities technically and politically.

Important efforts have been made for improving green water productivity and increasing food production, but what has been achieved is very limited with respect to what is planned and desired. What to be stressed hare is that we have the knowledge for improving water management in rain-fed agriculture to increase yield production, but there is a gap in the dissemination and use of this knowledge among the stakeholders from policy makers to the users, the small scale farmers.

In addition, the upgrading and investing in rain-fed agriculture is surrounded with several constrains including technical, socio-economic and policy factors and, above all, the inadequate investments in knowledge sharing and scaling-up of best practices. Unlocking potential in rain-fed requires large new investments in human capacity building, supporting research and institutional development as well as specific technologies.

Upgrading rain-fed agriculture requires integrated approaches to social and ecological management. The integrated approach to rainwater management must address links between investments and risk reduction and between rainwater management and land and crops management. Equally, there is a need for innovations in management of water that requires novel technologies and practices.

Strategies for upgrading, including technologies such as water harvesting and conservation agriculture are generally well known, but what are missing the social and economic processes and institutions that can link to suitable policies.

In most developing countries, where water is a constraint to food production, investments in water management in rain-fed agriculture should form a corn stone of any country's strategy for achieving the Millennium Development Goals.

Reducing poverty and hunger by half and ensuring the environmental sustainability is not possible without major contributions from rain-fed agriculture.

It is time for governments, development organizations and donors agencies to cancel completely the notion that rain-fed farming is a marginal activity and, instead, raise the awareness, promote investments to upgrade rain-fed agriculture to abandon the sectoral divide between irrigated and rain-fed agriculture and to place water resources management and planning more centrally in the policy domain of agriculture at large. Unlocking the potential of rain-fed agriculture is a long way and complex process, but we have to start even where water poses a particular challenge and to invest in tapping the potential that lies in the availability of adequate but erratic resource provided by rainfall.

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