Making the best of climatic variability: options for upgrading rainfed farming in water scarce regions

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Abstract Coping with climatic variability for livelihood security is part of everyday life for rural communities in semi-arid and dry sub-humid savannas. Water scarcity caused by rainfall fluctuations is common, causing meteorological droughts and dry spells. However, this paper indicates, based on experiences in sub-Saharan Africa and India, that the social impact on rural societies of climatically induced droughts is exaggerated. Instead, water scarcity causing food deficits is more often caused by management induced droughts and dry spells. A conceptual framework to distinguish between manageable and unmanageable droughts is presented. It is suggested that climatic droughts require focus on social resilience building instead of land and water resource management. Focus is then set on the manageable part of climatic variability, namely the almost annual occurrence of dry spells, short 2–4 week periods of no rainfall, affecting farmer yields. On-farm experiences in savannas of sub-Saharan Africa of water harvesting systems for dry spell mitigation are presented. It is shown that bridging dry spells combined with soil fertility management can double and even triple on-farm yield levels. Combined with innovative systems to ensure maximum plant water availability and water uptake capacity, through adoption of soil fertility improvement and conservation tillage systems, there is a clear opportunity to upgrade rainfed farming systems in vulnerable savanna environments, through appropriate local management of climatic variability.

Keywords Dry spells; savanna; water harvesting; yield

Introduction – upgrading rainfed agriculture in water scarce tropics
The challenge of improving livelihoods for the rural poor over the next 30–50 years is daunting. A precondition for success is wise use of water for food, in order to feed rapidly growing populations (still some 80 million new World inhabitants per year of which 95% grow up in developing countries).

The challenge is largest in two hot-spot areas, namely South Asia and sub-Saharan Africa, where rapid population growth, poverty and a weak natural resource base coincide. The challenge is more complex than during the first green revolution of the 1960s and 1970s, which lifted large parts of Asia out of an imminent food crisis. A new green revolution must focus particularly on upgrading agriculture among resource-poor smallholder farmers, of which a large portion live in tropical savannahs (semi-arid and dry sub-humid tropics) subject to high variability of rainfall. Furthermore, food increase in developing countries cannot originate from simple area expansion – as in the past e.g. in sub-Saharan Africa – but must instead increase in balance with ecosystems. We are thus faced with the challenge of a green-green revolution (Conway, 1997) with a strong focus on rural societies in poverty and water scarcity stricken tropics.

Furthermore, a new green revolution must pay particular attention to rainfed agriculture. The reasons are threefold. Firstly, the bulk of food originates and will originate from rainfed farming (80% of the agricultural land world-wide is rainfed, a number which exceeds 95% in sub-Saharan Africa). Secondly, despite large policy and management efforts to expand and improve irrigated agriculture, the pace of productivity and production increase is declining disturbingly. Environmental and social trade-offs from large dams are being felt and understood more widely among professionals and policy makers. Loss of irrigated farmland is often very high, due to salinisation problems. Finally, as will be shown
in this paper, there is a large untapped yield potential in rainfed agriculture, even in dry areas.

Unfortunately, despite the potential, only limited success has been achieved in upgrading rainfed agriculture among smallholder farmers in savannah agro-ecosystems. Yield levels of staple foods such as maize, sorghum, and millets oscillate around 0.5–2 t/ha, and have remained static for decades in many rural environments in sub-Saharan Africa. It has been tempting to mix-up these actual on-farm yield levels with achievable yields on-farm. Ample experience shows that this is wrong, and that instead a very large yield gap prevails in smallholder rainfed farming systems in tropical regions (FAO, 1993; Rockstrom and Falkenmark, 2000; Sivannappan, 1995; Tiffen et al., 1994; Torres et al., 2001; Zhu, 2004).

While it has been clearly shown that there are multiple reasons for this agricultural status quo – soil fertility depletion, poor timing of operations, late and inappropriate tillage, use of poor seed, inadequate weeding, weak markets etc. – water still remains the critical factor to enable an unlocking of an untapped potential to improved agricultural productivity.

This paper investigates the potential of boosting agricultural productivity – both in terms of yield per unit soil and water – through an integrated approach targeting the management of rainfall variability. Smallholder system innovations to manage periods of water scarcity (dry spells) are discussed and examples of successful water harvesting practices to mitigate dry spells are presented. Finally implications for risk management are discussed.

A large untapped hydro-climatic opportunity

Feeding the world of tomorrow will require large contributions from both irrigated and rainfed agriculture. However, there are good reasons to focus particularly on rainfed agriculture. Most food is, and will in the foreseeable future be produced from rainfed systems, and as shown by Pretty and Hine (2001) the largest opportunity for yield increases are found in smallholder rainfed systems. As shown by Rockström and Falkenmark (2000) there is a large yield gap in rainfed farming systems in semi-arid regions, where there is seemingly no agro-hydrological limitation to double or even quadruple yield levels of staple food grains. This is good news – it is rarely an absolute lack of water that causes yield loss, but rather the poor distribution of rainfall over time and in space – in other words – there is enough water but it is there at the wrong time.

Managing the manageable

In order to analyse the potential for upgrading rainfed agriculture in water scarce regions, it is useful to clarify the different time dimensions of climatic variability. The tendency is to focus vaguely on occurrence of droughts, without a clear definition of what is meant (Glantz, 1994). The result is a sense of despair, where every crop failure is blamed on droughts – causing a sense of hopelessness – after all what can one do when God fails to give us rain?! In recent studies it has been clearly shown that the occurrence of drought is highly exaggerated – where the late Anil Agarwal (2000) even states that India should never need to be subject to drought if only wise water management is adopted. Mwale (2003) in an analysis of drought occurrence in Malawi over the last 20 years, also shows that there is very little hydro-climatic support to the large number of government proclaimed droughts. Similarly, as indicated by Rockström (2003), the recent so-called droughts in Zimbabwe and Malawi, are largely politically induced and strongly exacerbated by societies affected by years of eroded social resilience and governance problems.

Instead of mis-using the term “drought”, it is useful to distinguish clearly between droughts and dry spells, and their origin – which is either due to meteorological conditions (low and/or poorly distributed rainfall) or agricultural management (poor rainfall partitioning leading to scarcity of root zone water despite adequate rainfall) (Figure 1).
Meteorological droughts occur statistically 1–2 times per decade in semi-arid tropical savannahs. This is a high occurrence, but still much lower than meteorological dry spells. Dry spells are short, often only 2–4 weeks long, periods of no rainfall, which affect crop growth. If occurring during stress sensitive growth stages such as flowering, the result may be complete crop failure. As shown by Barron et al. (2003), dry spells in semi-arid savannahs of Kenya and Tanzania occur almost seasonally, affecting crop yields and farmers’ risk perceptions. Meteorological droughts form a natural part of the hydro-climatic reality in savannah environments, and rural societies have over millennia built social coping mechanisms. The last century has seen a dramatic decline in social resilience to drought among rural communities, where, e.g. in the Sahel, good harvests which previously were stored to bridge drought years, today do not even suffice to carry a rural household from harvest to harvest.

Agricultural droughts and dry spells, where rainfall partitioning is added to the picture, are caused by deficit of soil water in the root zone. Due to large “losses” of water in the on-farm water balance – only some 5–15% of rainfall takes the productive flow path as green transpiration contributing to biomass growth – agricultural dry spells are seasonal occurrences in degraded smallholder farming systems. The matrix in Figure 1 indicates interesting management options. While meteorological droughts are unmanageable (other than by building social resilience), all other time and cause dimensions of rainfall variability are manageable.

Dry spell mitigation – system opportunities
Mitigating dry spells in rainfed farming systems requires the addition of a blue component (collection of runoff) in green rainfed farming systems (which use soil moisture from direct rainfall. This can be achieved through various practices of water harvesting for supplemental irrigation.

Figure 2 shows results from water harvesting research on dry spell mitigation combined with soil fertility management (Barron et al., 1999; Fox and Rockström, 2000). As seen from Figure 2, yield levels in the Burkina Faso case triple through integrated dry spell mitigation and soil fertility management compared to the present practice. Despite adding blue
water (60–80 mm/ha) water productivity increases. In the traditional farm practice 10,000 m³ of rainfall is required to produce one ton of grain (Burkina Faso) which is reduced to 5,000 m³ of water per ton for integrated water harvesting with soil fertility management.

**Where to start?**

There is little point in investing in blue water options such as supplemental irrigation, if the efficiency of present green water use is low. The first step in upgrading rainfed farming systems will always be to manage rainfall partitioning on the crop field. It is becoming increasingly clear that conventional tillage through ploughing may be one of the major causes of poor rainfall partitioning in farmers’ fields. Conservation farming is an interesting option to improve green water management, where soil inversion is abandoned (which has proven to cause extensive soil crusting, soil compaction and exhaustion of organic matter) in favour of tillage that aims at harvesting water in the soil through minimum disturbance (e.g. through ripping and sub-soiling). Figure 3 shows results from four years of animal drawn conservation farming trials on maize in semi-arid parts of north-western Tanzania.

**Figure 2** Grain yields from three years of on-farm trials on water harvesting for supplemental irrigation of maize (Kenya) and sorghum (Burkina Faso). Control: farmers’ traditional practice with no fertilizer (only manure) and only in-situ moisture conservation (terracing and micro basins); Water – supplemental irrigation during dry spells; Fertility – rainfed with fertilizer application; Water and Fertility – combining water harvesting with fertilizer applications

**Figure 3** Maximising the productive use of green water in rainfed farming. Conservation farming through ripping combined with soil fertility management. Water – Ripping in permanent planting lines breaking plough pans; Water + Nutrients – Ripping and fertilizer application; Nutrients only – conventional mouldboard ploughing and fertilizer; Ploughing only – farmers’ conventional practice
Conclusions – dry spell mitigation and risk management

Rainfall, the only truly random production factor in rainfed farming, affects farmers’ risk perceptions – and thus reduces incentives to invest in improved land management. Therefore, water management of the manageable part of rainfall variability, i.e. agricultural droughts and dry spells, may be the critical entry point to upgrading of rainfed agriculture.

Unlike the conventional analysis of the potential for upgrading rainfed farming in semi-arid tropics – generally (wrongly) defined as drylands – this paper puts forward the large inherent hydrological potential of savannah agro-ecosystems. An analysis of the manageable and unmanageable time dimensions of rainfall variability, indicates a large potential for increasing yields and water productivity through mitigation of dry spells. This requires adding blue – irrigation – components to green rainfed systems, using water harvesting strategies. As shown from on-farm experiences, it is only in combination with soil fertility management that the full effect of supplemental irrigation is achieved. Dry spell mitigation may be the key entry point to reduce risks of rainfall induced crop failure.

The experiences of water management in smallholder farming presented in this paper also indicate that green water management – through e.g. conservation farming combined with blue water management in green systems – e.g. through supplemental irrigation – may be the most promising avenue of unlocking the potential of smallholder rainfed farming. There seems to be a win-win-win solution at hand, where yields are improved while simultaneously enhancing water productivity and building of ecological and social resilience, which form the basis for livelihood improvement among rural poor.

References


