2 Zooming in on the Global Hotspots of Rainfed Agriculture in Water-constrained Environments

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Introduction

Rainfed agriculture is practised on 80% of the world's agricultural area and generates 60–70% of the world's staple food[1] (FAOSTAT, 2005). In semi-arid and dry subhumid zones, rainfed agriculture dominates food production systems, and water is a key limiting factor to crop growth (SEI, 2005). Since approximately 70% of the world's poor are women, the importance of rainfed sources of food weighs disproportionately on women (WHO, 2000). Agriculture plays a key role for economic development (World Bank, 2005), poverty reduction (Irz and Roe, 2000) and economic growth (van Koppen *et al*., 2005). Every 1% increase in agricultural yield translates to a 0.6–1.2% decrease in the percentage of absolute poor[2] (Thirtle *et al*., 2002). In sub-Saharan Africa for example, agriculture accounts for 35% of the gross domestic product (GDP) and employs 70% of the population (World Bank, 2000), and more than 95% of the agricultural area is rainfed (FAOSTAT, 2005). Thus, in this region, agriculture is the engine of overall economic growth and, therefore, broad-based poverty reduction (Johnston and Mellor, 1961; World Bank, 1982; Timmer, 1988; Abdulai and Hazell, 1995; IFAD, 2001; DFID, 2002; Koning, 2002).

There are thus strong reasons to believe that in many areas poverty is strongly influenced by agricultural production, which in turn is dependent on climate in general and water availability in particular. Despite the complex driving forces behind poverty, the social–ecological interactions between livelihoods, agriculture and water constraints make it important to analyse the degree of interdependence and the regions of the world where these factors interact. Identifying such regions can provide an important guide for new investments in upgrading rainfed agriculture.

The aim of this chapter is to identify global hotspots of rainfed agriculture where water constitutes a key limiting factor to crop growth. Thus, the focus is on the dry subhumid, semi-arid and arid zones. First, we investigate the link between climate and poverty. Thereafter, the number of people living in water-constrained agricultural areas is estimated. Based on this analysis, the global hotspots for rainfed agricultural areas in water-constrained environments are identified.

Most Poor Live in Water-constrained Environments

There is a correlation between poverty and water stress (Falkenmark, 1986). The UN Millennium

 Rainfed Agriculture: Unlocking the Potential (eds S.P. Wani *et al*.)

Development Project has identified the hotspot countries in the world suffering from the largest prevalence of malnourishment. These countries coincide closely with those located in the semi-arid and dry subhumid hydroclimates of the world (Fig. 2.1), i.e. savannah and steppe ecosystems. Of the 850 million undernourished people in the world, essentially all live in poor developing countries, which predominantly are located in tropical and subtropical regions (UNSTAT, 2005).

A Fifth of the World's Population Lives in Water-constrained Agricultural Areas

To make a quantitative assessment of the number of people depending on rainfed and irrigated agriculture for their livelihoods in different hydroclimatic zones, geographically distributed data was analysed. An overview of the data sets is given in Table 2.1. All data sets were re-sampled to a resolution of 2.5 min and continuous variables were reclassified into discrete classes, except for population.

Data on land use were derived from the Global Land Cover data set (GLC2000, 2003), in which the class 'cultivated and managed areas'[3] was chosen to represent the total agricultural area. Second, a data set produced by the FAO (Food and Agriculture Organization, the United Nations) was used to represent irrigated agricultural land use (Siebert *et al.*, 2005). This data set shows the percentage of the agricultural area equipped for irrigation. We

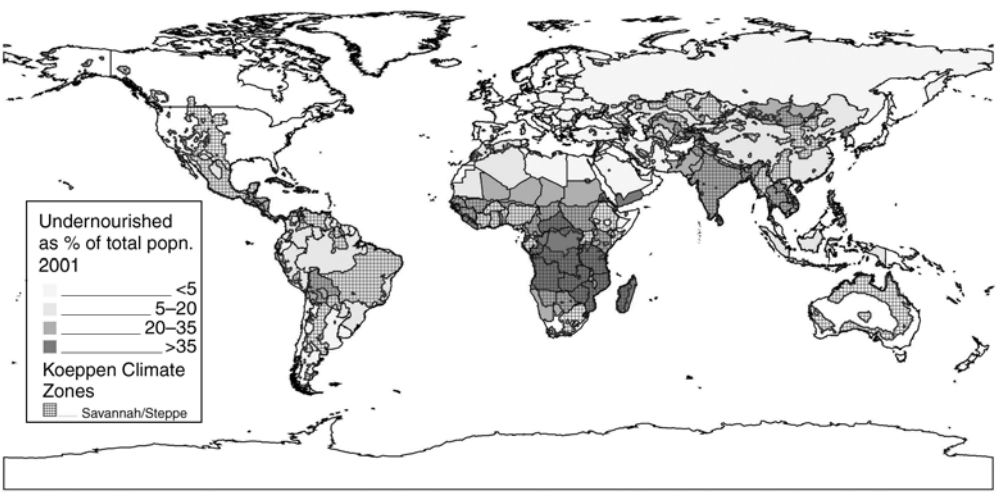

Fig. 2.1. The prevalence of undernourishment in developing countries (as percentage of population 2001/2002; UNSTAT, 2005), together with the distribution of semi-arid and dry subhumid hydroclimates in the world, i.e, savannah and steppe agroecosystems. These regions are dominated by sedentary farming subject to the world's highest rainfall variability and occurrence of dry spells and droughts.

Table 2.1. Datasets used in the analysis of hydroclimate, poverty and land use.

Dataset	Source (see text)	Resolution	Continuous data	Classes
Land use				
Agricultural land	GLC2000 FAO	0.5 min	NA[a]	Irrigated agriculture
Irrigated land	(Siebert *et al.*, 2005)	5 min		Rainfed agriculture/other
Hydroclimate	FAO based on CRU CL 2.0	5 min	Aridity index	Arid/semi-arid/dry subhumid/humid
Population	GPWv3	2.5 min	Number of people	NA[a]

[a] NA = data not available.

classified areas with more than 30% of the fields equipped for irrigation as 'irrigated agriculture', which corresponds to about 20% of the total agricultural area and is thus in accordance with the estimates by the FAO (FAOSTAT, 2003). Rainfed agricultural area was determined by subtracting irrigated agricultural area from the total agricultural area. This means that in pixels classified as irrigated, there might be rainfed fields as well, and vice versa. The classification is thus independent of rainfall amounts.

Water constraints are here defined only in terms of hydroclimate and described by an aridity index (AI)[4] provided by the FAO (2006). They created the AI data from climatic variables in the data set CRU CL 2.0 (New *et al*., 2002), and by calculating reference potential evapotranspiration according to the Penman-Monteith equation as described by Allen *et al*. (1998). Because AI was given as a continuous variable in the data set, it had to be reclassified into four hydroclimatic zones: arid (AI < 0.20), semi-arid (AI 0.20 to <0.50), dry subhumid (AI 0.50 to <0.65) and humid (AI > 0.65). A global population data set, Gridded Population of the World (GPWv3), produced by SEDAC (Socio-Economic Data and Applications Centre), was used in the analysis (CIESIN and CIAT, 2005). A methodological documentation of the GPWv3 is given in Balk and Yetman (2004).

The analysis shows that approximately 50% of the total global land area is located in water-constrained regions (Table 2.2), which is slightly higher in comparison with other studies (e.g. Safriel and Adeel, 2005). In particular, the estimate of the arid zone area deviates from the literature value. About 36% of the global population live in areas subject to water constraints, a figure which is in agreement with other estimates (Safriel and Adeel, 2005). Thus, it seems that the differences in area estimation of the arid regions make little difference in terms of population, probably owing to low population density in arid regions.

Agricultural area is about 13% of the total land area, which corresponds well with data found in FAOSTAT (2003; data for arable land and permanent crops). Although this area is rather small, almost half of the global population (47%) lives in agricultural areas. This is slightly higher than the estimation by FAO from the year 2000 of 42% (FAOSTAT, 2000).

These data sets were then used to calculate the number of people living in agricultural areas in the different hydroclimatic zones. The results show that about 1.11 billion people, corresponding to 17% of the total global population, lives from agriculture in water-constrained environments (Fig. 2.2). Out of that, almost half (8.2% of the world population) lives in rainfed agricultural areas, while the other half (8.9% of the world population) lives in irrigated agricultural areas. In the arid zone, more people live in irrigated agricultural areas compared with rainfed agricultural areas, which is to be expected since irrigation is needed to secure crop yields. On the other hand, in slightly wetter areas (i.e. semi-arid and dry subhumid), more people live in rainfed agricultural areas compared with irrigated agricultural areas.

Table 2.2. Area of land population in different hydroclimatic zones and land use areas from GIS analysis.

Region	Area (% of total land area)	Population[a] (% of total)
Hydroclimate		
Arid (including hyperarid)	23 (17)[b]	7.2 (5.8)[b]
Semi-arid	18 (15)[b]	16 (14)[b]
Dry subhumid	9 (9)[b]	13 (15)[b]
Total	50 (41)[b]	36 (36)[b]
Land use		
Rainfed agriculture	11 (9.7)[c]	28
Irrigated agriculture	2.1 (2.1)[c]	19
Total	13 (12)[c]	47 (42)[d]

[a] Figures in parenthesis are literature values; [b] Safriel and Adeel (2005); [c]FAOSTAT (2003); [d] FAOSTAT (2000).

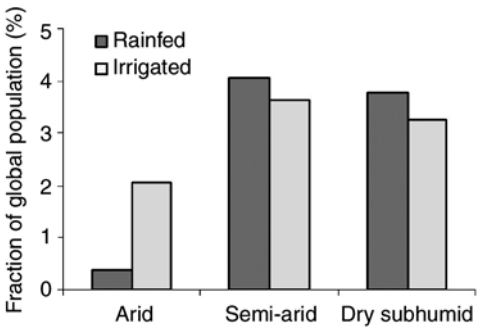

Fig. 2.2. Number of people in each hydroclimatic and land use zone in relation to the total global population.

Zooming in on the Hotspots for Water-constrained, Rainfed Agriculture

Three regions were identified as hotspots for water-constrained, rainfed agriculture, namely Africa, South Asia and East Asia (Fig. 2.3). Each of these regions hosts more than 100 million poor people depending on rainfed agriculture in water-constrained environments. Taken together, the total number of people in these three areas constitutes about 80% of all people living in water-constrained, rainfed agricultural areas, corresponding to 426 million people. In Africa, most of these people live in a band stretching from Senegal, through Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Ethiopia, Kenya, Tanzania, Zambia, Malawi, Mozambique, Zimbabwe and ending in South Africa. This area constitutes a large share of the total agricultural area in Africa, and in this region the prevalence of undernourishment is high (Fig. 2.1). The majority of the population living in water-constrained, rainfed agricultural areas in South Asia live in western India, and also partly in Pakistan and Afghanistan. Despite the fact that large parts of eastern India are agricultural land, this part of the country is substantially wetter, which explains the lack of people living in water-stressed conditions in that area. Lastly, in East Asia, the vast majority of the people living in water-constrained, rainfed agricultural areas are found on the north-eastern and north China plains. Although agricultural land extends further south in the country, it is only these two regions that are water constrained.

There is a clear difference between the three regions in terms of population density within the selected environment (Fig. 2.3); in Africa the population density is only about 0.5 persons per hectare, while it is more than four times greater in South Asia. Moreover, there is a difference between the three regions in terms of hydroclimate (Fig. 2.3). In comparison with the other regions, a relatively large part of the area is semi-arid in Africa, dry subhumid in East Asia, and arid in South Asia; however, in all three regions the semi-arid area dominates over the others, while the arid area is the smallest. Farming systems are similar in the three regions, with sedentary farming dominating in the semi-arid and dry subhumid regions, and with agropastoral systems in the transitional zone between dry semi-arid and semi-arid regions, particularly in Africa and East Asia. All three regions are dominated by small-scale rainfed farming, with a higher degree of mechanization in South and East Asia, as compared with Africa. Africa is the only region still practising (though limited) shifting cultivation.

Characteristic for Africa, South Asia and East Asia is that yields generally are lower than the world average[5], with a few exceptions (Fig. 2.4a). This can be viewed as an opportunity for improvements in the form of investments into water management in these regions, given the large opportunities for improved agricultural and water productivity even in water-constrained regions. Moreover, GDP is very low in both Africa and South Asia, in comparison with the world average, and also a little bit below the world average in East Asia (Fig. 2.4b). Poverty is thus generally prevalent in these regions, which hampers investments in agricultural inputs such as water management techniques and nutrients. The large number of people who depend on rainfed agriculture in water-constrained environments, the low yields and the high incidence of poverty in these regions can also be interpreted as a cause and effect relationship between water availability, crop production and poverty. In other words, where water limits crop production, poverty is strongly linked to variations in rainfall and to the farmers' ability to bridge intraseasonal dry spells. Livelihoods depend strongly on water availability, a relationship that is well established for economies highly dependent on the

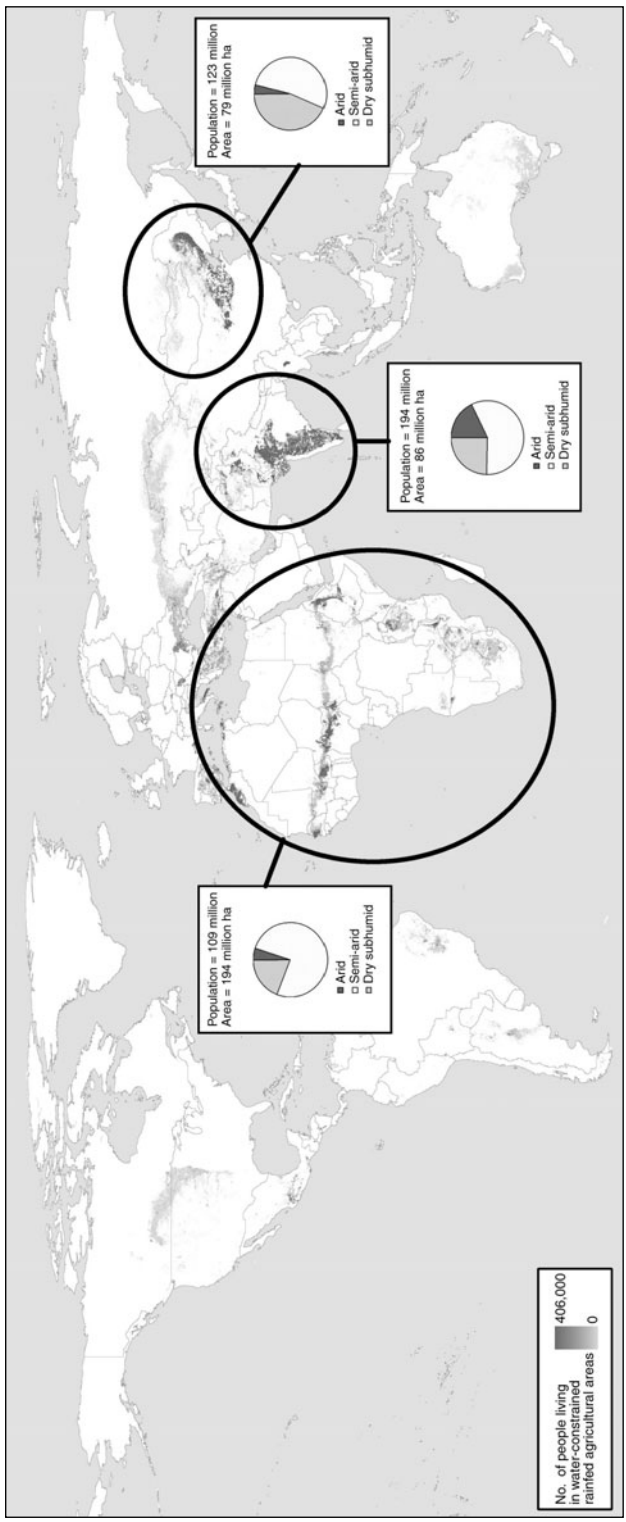

Fig. 2.3. Number of people living in water-constrained, rainfed agricultural areas. The three circles indicate the occurrence of global hotspots where more than 100 million people live.

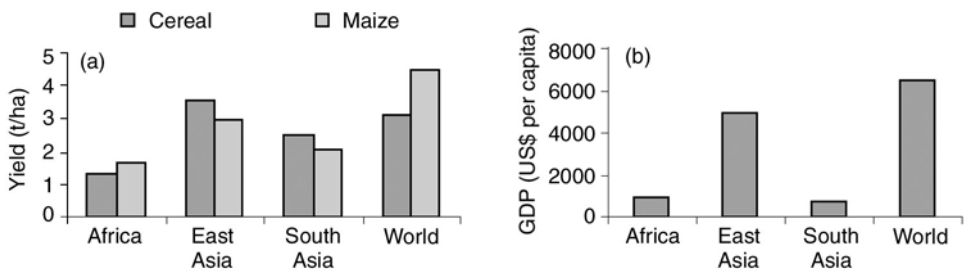

Fig. 2.4. Comparison between (a) average yields (FAOSTAT, 2003) and (b) gross domestic product (GDP) (UNSTAT, 2004) for the three global hotspot regions for water-constrained, rainfed agriculture. Cereals include barley, maize, millet, oats, rice, rye, sorghum and wheat. GDP for South Asia also includes data for Central Asia.

agrarian sector, resulting, for example, in a close correlation between average annual rainfall and GDP growth (Brown and Lall, 2006).

Linking Poverty, Land Use and Hydroclimate

Assessments of the relationships between poverty, hydroclimate and land use have previously not been conducted at a sub-national level, and therefore estimates on the number of poor that depend on rainfed agriculture as their main source of income, in areas where water poses constraints on agriculture, are still lacking. This chapter provides an identification of the global hotspots for combined water stress and rainfed agricultural land use. Moreover, the relationship between poverty and hydroclimate is discussed. The next step would be to quantitatively estimate the number of poor living off rainfed agriculture in water-constrained environments; however, such an analysis requires reliable global poverty data at a high resolution.

Conclusions

Poverty generally seems to be relatively prevalent in water-constrained areas. This could be due to the fact that many poor people's livelihoods depend on crop production from rainfed agriculture in water-constrained environments. It is estimated that about 1.11 billion people, corresponding to 17% of the total global population, live in agricultural areas in water-constrained environments, and out of that 8.2% of the population, lives specifically in rainfed agricultural areas. In Africa, East Asia and South Asia more than one million people in each region live in rainfed agricultural areas where water poses a key constraint for crop production. These regions are characterized by low crop yields and GDP levels. Again, this could be interpreted as an effect of water constraints on crop production, which in turn could affect poverty in regions where many people derive their livelihoods from rainfed agriculture. The conclusion would thus be that investments in water management to upgrade rainfed agriculture in these hotspot regions are likely to have a large impact on poverty reduction. Moreover, the Millennium Development Goals on hunger and poverty require increased focus on water management in rainfed agriculture.

Acknowledgements

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Notes

[1] Food that forms the basis of a traditional diet, and thus varies from place to place. Typically inexpensive starchy foods of vegetable origin, e.g. cereals that are high in calories and carbohydrate and that can be stored for use throughout the year.

[2] Poverty is generally understood as the condition of having little money and few material possessions. Factors that are part of poverty include: precarious livelihoods, excluded locations, physical limitations, gender relationships, social relationships, lack of security, abuse by those in power, limited capacities, disempowering institutions and weak community organizations. The term 'absolute poor' used in the chapter refers to poverty in relation to an absolute poverty threshold. In this chapter the term 'poor' refers to those 850 million people that are undernourished according to UNSTAT (2005).

[3] This class includes herbaceous, shrub and tree crops (irrigated and rainfed), as well as flooded crops.

[4] Precipitation divided by potential evapotranspiration.

[5] In the African hotspot, the main crops are maize, millet and sorghum, in South Asia it is millet and wheat and in the China hotspot it is wheat, maize and soybean.

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