Where do poverty and drought-prone crop production coincide?

A key issue in the quest for better targeted technology generation, adaptation and delivery

Where across the world are poverty and drought-prone crop production in concert? In 2006, Generation Challenge Programme scientists[1] developed and applied a new method for identifying such areas. This analysis of global spatial datasets identified five farming systems in South Asia, five in sub-Saharan Africa, four in East Asia, and one in Mesoamerica where drought coincides with high levels of poverty. The farming systems are home to more than 70 percent of the world's stunted children, stunting being one of the most reliable indicators of malnutrition and poverty. These rural dwellers heavily rely on 12 staple food crops. It is in these areas, and with these crops, that agricultural research efforts are likely to have the largest impact on reducing poverty.

1 Background

1.1 Study rationale

The unprecedented advances in international agricultural research over the past 50 years have contributed greatly to decreasing poverty and malnutrition. However, in spite of these advances, the absolute number of poor and hungry people has increased across sub-Saharan Africa, central and eastern Africa, and South Asia. In other words, the world's poorest and most vulnerable farmers have largely failed to benefit from this research. Most advances have occurred in the more favourable cropping environments, especially those with irrigation, consequently raising the living standards of farmers who were already relatively better-off.

The Generation Challenge Programme (GCP) of the Consultative Group on International Agricultural Research (CGIAR) was launched to catalyse high-impact research that would contribute substantially and rapidly to reducing poverty. GCP's work focuses on developing and delivering genomic products and services to support the breeding of more drought-resistant food crops—a crucial intervention for improving the food security and livelihoods of poor rural people.

[1] This brief is a condensed and simplified version of a paper by Hyman G, Fujisaka S, Jones P, Wood S, de Vicente C and Dixon J, 'Strategic approaches to targeting technology generation: Assessing the coincidence of poverty and drought-prone crop production.'

One of GCP's major concerns is therefore to identify the priority regions and crops on which to focus in order to have the greatest impact on reducing poverty. Consequently, GCP-commissioned a study in 2006 to identify the areas in the developing world where large-scale poverty and frequent droughts coincide, as it is well known that droughts substantially reduce crop productivity and are therefore an underlying key cause of poverty. The study used new spatial data and analytical tools to improve the accuracy with which these areas can be identified.

The Millennium Development Goals (MDGs) commit the global community to eradicating extreme poverty and hunger. The dependence of the rural poor on agriculture for their basic needs means that increasing the productivity of the farming systems where the poor live is crucial for achieving these goals.

GCP is a part of the growing international commitment to accelerating progress on reducing poverty and hunger by refocusing development efforts on resource-poor farmers in marginal environments.

1.2 Methodology

The study took global spatial data sets on crop production, climate and poverty and used a combination of spatial overlay, drought modelling and descriptive statistics to identify the areas where the outputs of crop improvement research would likely have the largest impact on reducing poverty.

Farming systems were used as the geographic units of analysis, and malnutrition—as identified by childhood stunting—was taken as a proxy for poverty. From this, a model was developed that identifies the areas where human poverty and the impact of drought on crop production are most pronounced. The study also revealed the main staple food crops with highest relative importance in the farming systems.

Data on population, poverty and crop production

The scientists first developed a spatial database of population, poverty, and crop production and fed these data into a geographic information system (GIS). They used child stunting (low height-for-age) as the principal indicator of poverty because it is highly correlated with households that cannot provide sufficient food or income for healthy nutrition; and its measurement is relatively straightforward and comparable globally, which is not the case for other indicators.

The data on crop production were developed using FAO digital crop maps for the 19 major food crops of the developing world; estimates of the spatial distribution and productivity of crops; and sub-national data from agricultural censuses and surveys. Irrigated areas were excluded from the study, as poor farmers in marginal environments have little access to such areas.

Farming systems

For its geographical unit of analysis, the study took the 63 farming systems delineated by Dixon et al[2]. but excluded the 11 urban-based farming systems due to their small size. These 63 farming systems were compared according to their levels of poverty, crop production and drought by converting the data on these factors in to 10-km^2 grid cells within each system. GIS software was then used to calculate population, poverty and crop production statistics for each agricultural region.

Assessing drought frequency

To map drought risk, the scientists developed a model that estimates the probability of the growing season failing in each farming system. A failed season was defined as one with rainfall at the start sufficient for germination and establishment, having less than 50 growing days, and

[2] 2001. 'Farming Systems and Poverty', FAO–World Bank.

having a sudden (clearly defined) end. Note that this definition is generic and its applicability to a given crop in a given location w serves as a general way of describing when crops are likely to fail due to drought and does not apply to specific crops. For example, long-season maize might fail in a season in which short-season m ould depend on many specifics such as the real length of the growing period.

The growing season failure model was built around a number of fixed generic parameters for the water storage capacity of soils, the start and end of the growing season, and the availability of soil moisture. This modelaize might produce a reasonable yield.

The scientists also developed two drought indicators. The potential drought impact index (PDII) shows how much crop production is lost due to drought in non-irrigated crop areas. This index is designed such that, in systems where the probability of drought is low, the index may still be high if the cultivated area is large meaning that drought will affect many people's food security.

The second drought indicator is the mean probability of a failed season within a farming system ('Avg fail' in Table 1). This indicator locates the most drought-prone and marginal environments.

Table 1 Farming systems with over 2.5 million stunted children ranked according to the failed seasons drought model

Farming system	Region	Stunted children ('000s)	Stunting prevalence (%)	PDII	Avg fail	Rank[b] Global	Rank[b] Regional
Rainfed mixed	SA	24547	63	8,176,456	16	1	1
Lowland rice	EAP	13368	34	7,963,917	15	2	1
Cereal-root crop mixed	SSA	6319	43	5,331,317	17	3	1
Rice-wheat	SA	28310	52	4,050,261	42	4	2
Upland intensive mixed	EAP	15435	35	3,725,591	28	5	2
Agro-pastoral millet/sorghum	SSA	3135	37	2,633,259	52	6	2
Rice	SA	11664	51	2,632,872	5	7	3
Maize mixed	SSA	46318	43	2,535,536	23	8	3
Root crop	SSA	4989	40	1,802,876	8	10	4
Dry rainfed	SA	13610	65	1,227,981	31	14	4
Maize-beans (Mesoamerica)	LAC	2837	37	1,218,125	15	15	4
Highland temperate mixed	SSA	2761	50	909,683	18	21	7
Temperate mixed	EAP	2596	26	849,686	77	23	3
Highland mixed	SA	5162	48	827,142	18	24	5
Highland extensive mixed	EAP	2537	44	682,635	12	28	5

a. SA, South Asia; EAP, East Asia and the Pacific; SSA, sub-Saharan Africa; LAC, Latin America and the Caribbean.

b. Both global and regional rankings are based on non-irrigated crop area.

Beyond the central aim of identifying where drought and poverty coincide, the methodology also allowed this reference study to 1) assess the distribution of drought frequencies within the farming systems, 2) identify the mix of crops grown under different drought frequency conditions across the farming systems and 3) show the extent of areas under all probabilities of failed seasons.

2 Results

2.1 The number of stunted children

The study area covers 5 billion of the planet's 6 billion people, with about 60 percent of them living in rural areas. It is home to 70 percent of the world's stunted children. The prevalence of stunting within the 63 farming systems was found to range from a high of 63 percent of all under 5

year-olds in the 'rainfed mixed' farming system of South Asia, indicating high levels of malnutrition, to only 5 percent in the 'mixed intensive' system of the Latin America and Caribbean region.

In most cases, the farming systems with the highest prevalence of stunted children also have the highest absolute numbers of stunted children. However, the absolute numbers vary considerably. Of the 20 systems with the highest numbers of stunted children, only one had a prevalence of less than 34 percent—the 'temperate mixed' system of East Asia.

Of the 10 farming systems with the highest number of stunted children, four are in South Asia and three each are in sub-Saharan Africa and in East Asia and the Pacific. Eight of the 10 systems with the highest percentage of stunted children are in South Asia, with the remaining two in sub-Saharan Africa. Thus, in terms of both absolute numbers and prevalence, South Asia emerges as the region most severely affected by hunger and poverty.

Note that rural population data indicate that systems with high numbers of stunted children also have high rural populations. Unfortunately, no global data set is available that distinguishes between urban and rural stunting, potentially biasing the study's results towards the farming systems that include large cities.

2.2 The impact of drought

Drought analysis allowed the study to identify areas where many people can—and do—grow crops and where drought badly affects food security.

The 10 farming systems with the largest potential impact of drought on the production of staple food crops are in South Asia (3 systems), sub-Saharan Africa (4), East Asia (2), and Latin America (1). Most of these appear in Table 1.

Most of the systems in the Middle East and North Africa fall in the lower half of the ranking for drought impact because of their smaller cultivated areas. Many low-ranking systems still have a very high likelihood of failed seasons. These are mostly arid farming systems with small cultivated areas. For example, sub-Saharan Africa's so-called 'sparse arid' system, found on the margins of the Kalahari desert, has a 94 percent probability of failed seasons but, for this very reason, has very little area under cultivation.

The values for the mean probability of a failed season (avg fail) varied widely across the 63 systems. Some of the systems with the largest potential drought impact index have a relatively low likelihood of crop failure. For example, sub-Saharan Africa's 'root crop' system has a high potential drought impact index, indicating large areas susceptible to drought, but droughts in fact occur relatively infrequently. It is the large cultivated area of the system that generates high losses on production, and the two factors combined affect large numbers of people.

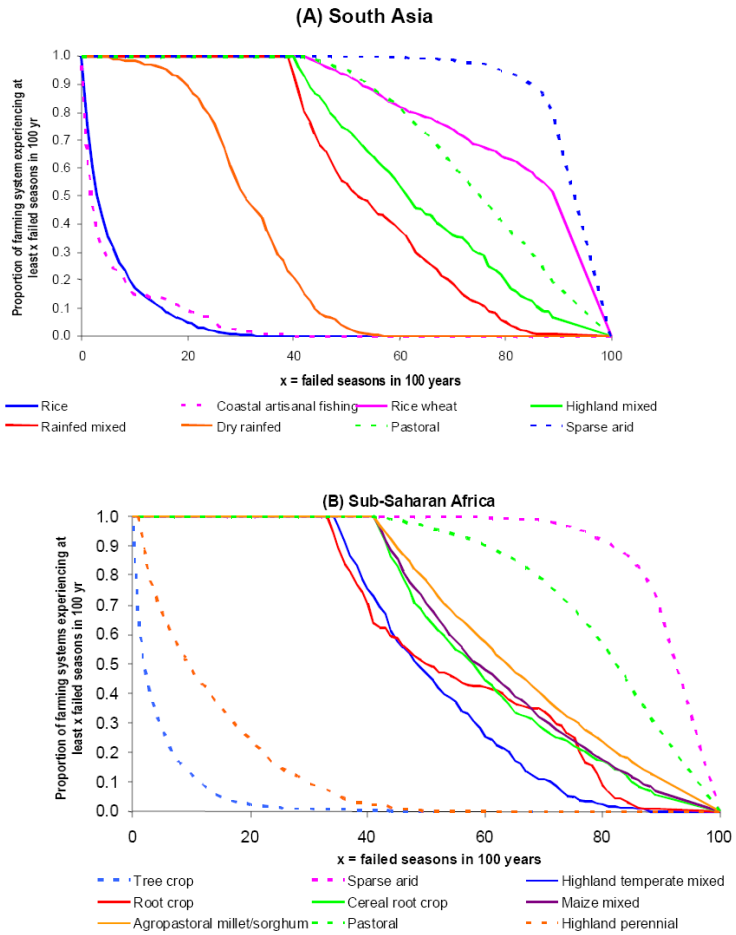
2.3 The frequency of drought

The study identified large variations in the incidence of drought both within and across the farming systems. Unsurprisingly, the driest systems have large areas where the probability of a failed season is high, whilst in well-watered systems drought hardly ever occurs. In these two types of systems the same crops tend to be grown year-on-year as the growing conditions tend to be stable. In between these two extremes are systems that experience considerable variability in the frequency and severity of drought. Thus, cropping patterns are more diverse, as farmers hedge their bets by planting different crops and adapting their farming systems according to changing conditions.

Figure 1 shows the distribution of drought in the two most poverty-stricken regions of the world—South Asia and sub-Saharan Africa. With the exception of the South Asian 'rice' system, all the systems show a wide range of drought frequency reflected in the relatively gently sloping curves. The curves closer to 45 degrees represent more varied environments for crop growth where

farmers cope with uncertainty by growing a wider range of crops in mixed crop-livestock systems.

Figure 1 The proportion of area within each farming system experiencing at least a given number of failed seasons in a 100-year period for (A) South Asia and (B) sub-Saharan Africa. (Systems represented by solid lines are among the 15 systems of the world with more than 2.5 million stunted children)



2.4 Poverty and drought combined

Overall, the analysis found poverty and drought to be more severe in the farming systems of Asia and sub-Saharan Africa and less so in Latin America. Table 2 shows the top 15 farming systems ranked by the absolute number of stunted children. Each of these systems has more than 2.5 million stunted children. Interestingly, the systems not included in the table, in which the numbers of stunted children fall below 2.5 million, were ones in which livestock makes a more substantial contribution to livelihoods and food security than do food crops.

Table 2 The 15 farming systems with the most stunted children, ranked with global (fsg) and regional (fsr) potential drought impact index rankings, and staple crops most widely grown

Farming system [a]	Stunted children ('000s)	Crops	fsg	fsr
SA rice wheat	28310	*Rice, pulses (chickpea) millet, wheat, maize, bean*	4	2
SA rainfed mixed	24547	Rice, millet, *sorghum*, chickpea, bean, *groundnut*, maize, wheat	1	1
EAP upland intensive mixed	15435	Maize, rice, wheat, *sweet potato, potato*, bean	5	2
EAP lowland rice	13368	Rice, maize, wheat, sweet potato, groundnut	2	1
SA rice	11668	Rice, pulses (chickpea)	7	3
SSA cereal-root crop mixed	6319	Sorghum, millet, *pulses (cowpea),* maize, groundnut, cassava	3	1
SSA maize mixed	6318	Maize, cassava, sorghum, pulses, groundnut, millet, bean, sweet potato	8	3
SA highland mixed	5162	Rice, maize, wheat, potato, groundnut, pulses (chickpea)	24	5
SSA root crop	4989	Maize, cassava, rice, sweet potato, cowpea, sorghum, groundnut, bean	10	4
SA dry rainfed	3610	Sorghum, millet, chickpea, groundnut, bean	14	4
SSA agro-pastoral millet/sorghum	3135	Millet, sorghum , pulses groundnut, maize	6	2
LAC maize-beans	2837	Maize, bean, sorghum	15	4
SSA highland temperate mixed	2761	Maize, wheat, sorghum, *barley*, millet, pulses	21	7
EAP temperate mixed	2596	Maize, wheat, potato, groundnut, millet	23	3
EAP highland extensive mixed	2486	Rice, maize, wheat, potato, groundnut, pulses	28	5

a. SA, South Asia; SSA, sub-Saharan Africa; LAC, Latin America and the Caribbean; EAP, East Asia and the Pacific.

b. Crops appearing for the first time in the list are in italics.

The five systems with the highest number of stunted children all occur in Asia and have over 10 million stunted children each (see Table 2). These systems are marked by large populations and large cultivated areas. They also make up five of the seven most drought-susceptible systems. Sadly, despite being one of the cradles of the Green Revolution, the South Asian 'rice-wheat' system has the highest absolute number of stunted children (28 million) and ranks fourth on the drought index. South Asia's 'rainfed mixed' system has the second-highest number of malnourished children and is the system where drought has the greatest impact on human welfare. In East Asia and the Pacific the 'lowland rice' system has slightly more stunted children than the 'upland intensive mixed' systems although the latter system is more drought prone ranking second globally.

Four of the world's most drought-prone areas are in sub-Saharan Africa. The 'cereal–root crop' and the 'maize mixed' systems, with 6.3 million stunted children each, span the southern part of the Sahel and a large part of East Africa and have high rural populations. The 'root crop' system has almost as many stunted children (over 5 million) and lower, but still relatively high, drought intensity. The other notable system in this region is the Sahelian 'agro-pastoral millet-sorghum' system, with more than 3 million stunted children and ranking sixth for drought intensity.

The analysis found the Latin America and Caribbean region to be less poverty stricken than Africa and Asia and to suffer less from drought. Only one farming system in this region has more than 2.5 million stunted children. The 'maize-bean' system in Mexico and Central America has 2.8 million such children and is globally the fifteenth most susceptible system to drought.

The farming systems in Eastern Europe and Central Asia and in the Middle East and North Africa have fewer poor people and a lower cultivated area susceptible to drought. Less cultivated area is susceptible to drought because it is so dry that almost no land is good for agriculture. While these regions do suffer drought and poverty, substantially fewer people are affected. The areas

involved tend to be characterised by backward rural 'pockets' where conditions may be locally severe or severe only in certain seasons or years.

The study's results therefore confirm a high correlation between poverty and drought. The drought rankings of the 15 systems (see Table 1) are all within, or near, the top third of the 63 farming systems globally. Nine of the 15 systems are in the top 10 of the drought ranking. Only the East Asia 'temperate mixed' system (drought rank 23) and the East Asia 'highland extensive' mixed system (drought rank 28) fall outside the top third of the 63 systems.

2.5 The food crops poor farmers rely on

The study also sought to find out which crops poor farmers rely on the most by examining a global database of harvested area and production. This analysis identified the following 12 crops as covering at least 5 percent of the cultivated area of each of the 15 farming systems stricken most by poverty and drought.

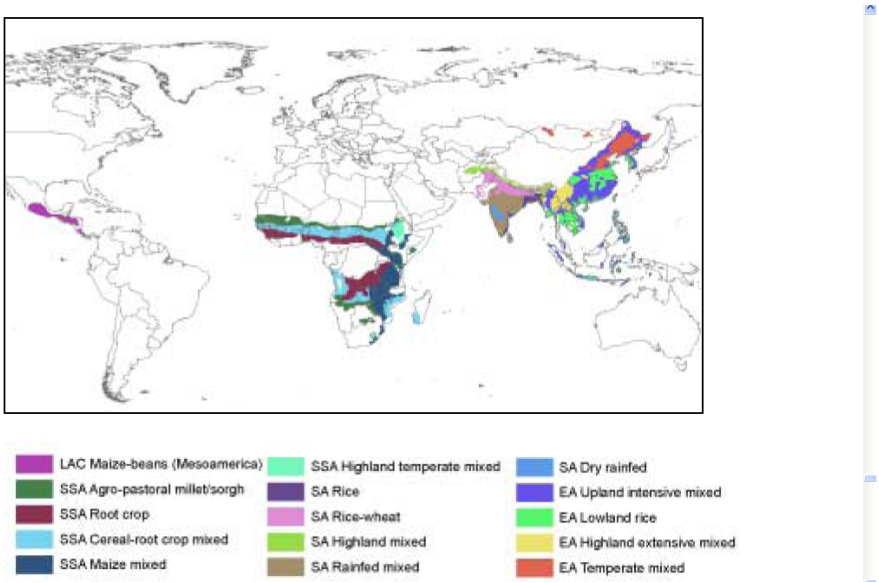
- Rice
- Wheat
- Chickpeas
- Maize
- Millet
- Sorghum
- Groundnuts
- Cowpeas
- Cassava
- Sweet potatoes
- Beans
- Barley

This strongly suggests that poor farmers in drought-prone areas rely heavily on these crops to feed their families and to maintain their livelihoods.

3 Conclusions

The study identified a strong correlation between the occurrence of poverty and drought in the world's farming systems and identified the 15 areas where this is most pronounced (see Figure 2 and Tables 1 and 2). These results suggest that these 15 farming systems, and the associated 12 crops that the rural people in these areas rely on, should be prioritised for agricultural research and development. These systems account for a substantial proportion of the world's poor and include over 70 percent of the world's stunted children.

Figure 2 Priority farming systems for targeting agricultural research for poverty alleviation



SA, South Asia; SSA, sub-Saharan Africa; LAC, Latin America and the Caribbean; EAP, East Asia, and the Pacific.

With few exceptions, the poorest, most drought-susceptible systems have diverse environments and farmers have developed effective mechanisms to cope with risk. These farmers cope by

diversifying their sources of livelihoods, including livestock keeping. The judicious employment of improved crops in these areas may well be successful if the varieties can be fitted into such diverse and risky systems.

The databases developed and used in this study have great potential for priority-setting on initiatives aimed at improving the productivity of agriculture in the developing world. The results of this assessment can help to focus agricultural research and development investments on a reasonable number of priority regions and crops that are likely to have the greatest impact on reducing poverty.

This initial work has great potential to be developed further. The main limitation of this modelling exercise has been the aggregate scale of its analysis. This and other limitations could be overcome by including other poverty indicators and poverty analysis at finer geographic resolutions. Further work could also develop crop-specific drought models that distinguish the main drought types according to the stages of the crop cycle to provide more detailed information for crop improvement programmes. The data types and parameters used in this initial reference study could easily be modified to reflect other priorities.