Improving water use in rainfed agriculture in the Greater Mekong Subregion

IWMI International Water Management Institute

CIAT Centro Internacional de Agricultura Tropical International Center for Tropical Agriculture Consultative Group on International Agricultural Research

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in the Greater Mekong Subregion

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Credits

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Contents

Main messages and recommendations

Diverse farming conditions exist across the GMS

- The Greater Mekong Subregion (GMS) has six agro-ecological zones (AEZs), each with broadly similar biophysical conditions and farming systems, though with local variants in each country and different levels of transition from traditional subsistence systems to more modernized, market-oriented intensive production.

- Farming systems fall into two distinct groups: 'lowland' systems, where inundated rice production predominates and 'upland' systems, where rice and a mixture of other crops are grown under non-flooded, aerobic conditions.

- Both systems exist in all AEZs, depending on local topography. However, inundated rice systems prevail in the deltas and lowland plains, while upland systems are more widespread in the sloping uplands and highlands.

Climate variations make life difficult for farmers

- Annual rainfall is sufficient to support rainfed cropping but the very marked seasonal distribution, driven by the southwest monsoon, restricts the growing season to between six and eight months of the year. Crops are vulnerable to shifts in the timing of rainfall, with the late onset or early cessation of wet-season rains affecting production in both wet and dry seasons.

- Production losses associated with drought are usually induced by short-term rainfall deficits within the wet season rather than by shortfalls in total annual rainfall. For flood-recession agriculture in deltas and lowlands, water levels in the major rivers are important for both rainfed cropping and irrigated production.

- Analyzing the suitability of a range of major crops for rainfed cultivation emphasizes the critical importance of water management in regional production, since crop-growth models indicate that most crops are constrained by rainfall. For example, paddy rice, the region's major crop, is highly sensitive to water availability and only suitable for cultivation with careful water management.

There is good potential to improve yields

- Yields of many crops have increased over the last 20 years, thanks to more effective water management, improved varieties and better agronomic practices. However, some yields remain low.

- A first major yield gap is where lowland rice is cultivated in traditional wet-season paddy systems on the lowland plains of Cambodia, northeast Thailand, Lao PDR and Myanmar. Yields can be improved by better use of supplementary irrigation and high-yielding varieties. In Vietnam, major improvements have come from a shift to fully or partially irrigated crops at the beginning and end of the dry season.

- A second yield gap occurs in the uplands, across a range of crop types. Very significant gains in yields have been made in Yunnan's uplands by farmers cultivating aerobic rice varieties combining drought resistance with high yield, using integrated agronomic practices including partial irrigation, or alternate wetting and drying. Large increases in productivity could also be realized through a shift to montane paddy, where suitable land is available or can be created through terracing.

Better water management is key to achieving the region's potential

- Water management is a critical first step in improving yields; when water-related risks are reduced, farmers are more willing to invest in other yield-increasing strategies. A wide range of existing technologies and approaches could help farmers manage water better in agricultural systems.

- There are opportunities for introducing water-management interventions at farm, community and larger scales. Collective small-scale interventions may be able to achieve similar outcomes to large-scale projects, but with lower costs and greater ownership and involvement by farmers.

- The potential for expanding groundwater use is high, particularly in the large alluvial systems of the region's major rivers, where the annual flood replenishes 'natural underground irrigation systems'.

- Agricultural systems across the GMS are changing rapidly, driven by a complex mix of large-scale forces and unplanned individual land-use choices. Discussions on sustainability need to encompass how landscapes can function as a whole while supporting the fundamental ecosystem services that underpin agricultural production. Promoting a mix of farming enterprises that can support livelihoods and improve biophysical and economic resilience is preferable to simply assessing the potential for individual crops.

Introduction

The Greater Mekong Subregion (GMS) comprises the five mainland Southeast Asian nations of Cambodia, Lao PDR, Myanmar, Thailand and Vietnam, along with the southern Chinese provinces of Yunnan and Guangxi. Home to around 313 million people, rapid development over the last 20 years has made it a new frontier of Asian economic growth. To keep pace with growing populations and dietary changes, food production in the GMS will need to increase by an estimated 25% over the next 15 years. The economies of the region are still essentially agricultural, at least in terms of the workforce employed in the sector. Economic growth in agriculture is important for reducing poverty and fueling expansion of other sectors. Increasing production is required both for food security and to underpin economic development. Food production in the GMS is not only important for national food security but also contributes to international food markets, since both Thailand and Vietnam are major exporters of rice.

The majority of agricultural production systems in the GMS receive all or most of their water from rainfall, and thus are vulnerable to climate variability. There is great potential for improving productivity, sustainability and resilience in these systems, particularly by better control and use of water resources. All national governments consider expanding their irrigation to be an important priority. Irrigated areas are increasing but economic and physical constraints prevent full implementation in some areas. Upgrading rainfed agriculture promises large social, economic and environmental paybacks, particularly in terms of reducing poverty and boosting economic development.

International discussions about water for rainfed agriculture have focused on water shortages in arid and semi-arid zones, and have paid less attention paid to the specific challenges of rainfed agriculture in relatively water-rich humid and sub-humid systems. The GMS lies within the humid to sub-humid tropics, and total annual rainfall exceeds 1,000 mm in most areas. Absolute water shortage is not the primary issue, but yields are much lower than they could be and water stress is a significant constraint to production. The strongly seasonal nature of rainfall and flows means floods and droughts are common.

Agro-ecological zones of the GMS

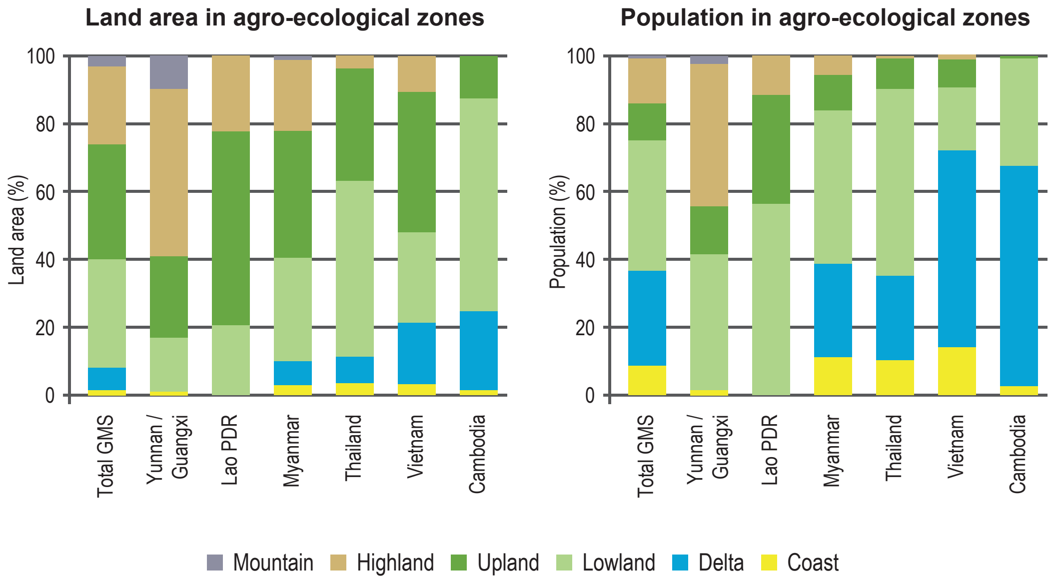
The GMS is culturally and geographically diverse, but can be divided into six broad agro-ecological zones (AEZs), which share common production systems and are subject to similar biophysical constraints and risks. These AEZs comprise:

- mega-deltas of the Red, Chao Phraya, Irrawaddy and Mekong rivers (including the Tonle Sap Floodplain);
- coastal zones, which rise rapidly to coastal ranges;
- lowland plains of northeast and central Thailand, Myanmar's dry zone, Lao PDR's Mekong floodplains, plus north and northeast Cambodia;
- tropical uplands of Guangxi Province in China, northern Thailand, northern and central Lao PDR, northern and central Myanmar, central and northern Vietnam;
- subtropical highlands of Yunnan Province, eastern and western hills in Myanmar, Dalat Plateau of Vietnam, and the Bolovens and Xiengkuang plateaux in Lao PDR; and
- peri-urban zones around the region's major cities.

The relative distribution of these agro-ecologies varies widely between the six GMS countries. The deltas and lowlands make up more than 85% of Cambodia, while upland and highland areas comprise more than 75% of Lao PDR and southern China (Yunnan and Guangxi). Populations are concentrated in the deltas, lowlands and coasts relative to the uplands and highlands, except in mountainous Yunnan (Figure 1).

Figure 1

Distribution of land area and population within agro-ecological zones of the GMS



The agro-ecological zones are not rigidly defined areas, but provide a useful means to assess the interactions and dependencies between agricultural production systems and the ecosystems that support them (Figure 2). Rainfall varies considerably across these zones but topography generally exerts a stronger control on farming systems than rainfall in these areas.

Modes of agricultural production vary according to the natural resources available and the degree of economic development. Agriculture in the GMS is in transition from traditional subsistence systems to modern commercial production. The extent of travel along this trajectory varies enormously both within and between countries, but the overall direction of change is very similar: intensification, specialization, increased inputs and mechanization. Given the diverse levels of economic development within the region, farming systems have progressed to different levels within each zone in different countries. The more developed countries (such as Thailand and China) can be seen as models of where the less-developed countries (such as Lao PDR and Cambodia) may be heading.

Figure 2

The nations and agro-ecological zones of the Greater Mekong Subregion

Subtropical highlands

Farming systems: A wide range of crops, including paddy rice, wheat, potatoes, vegetables, flowers, tobacco, coffee, sugarcane, tea, rubber, pepper, fruit trees, cocoa and mulberry. Rice is grown as montane paddy, upland rice or irrigated aerobic rice.

Water management: Intensive irrigation for high-value horticultural crops. Partial irrigation for some cash crops (tobacco, vegetables, coffee). Water sources include rivers, small-scale storage and groundwater. Terracing for montane paddy in Yunnan.

Peri-urban zones

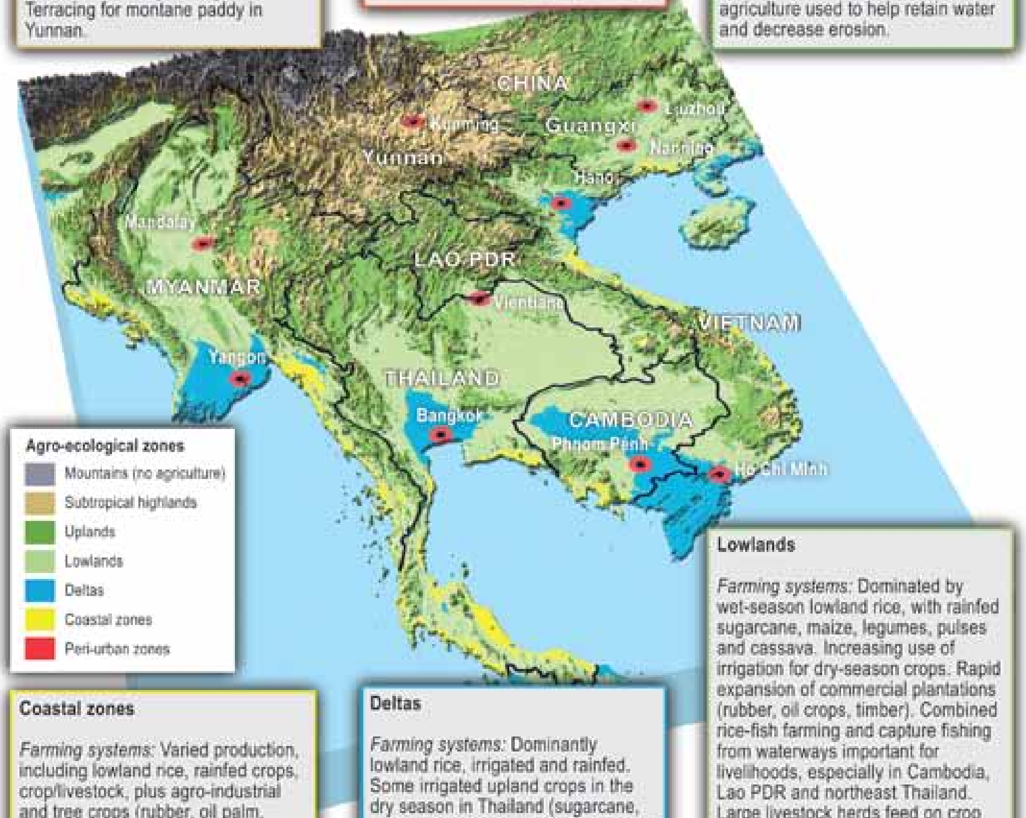
Farming systems: Intensive horticulture and orchards, with irrigation from rivers. Intensive livestock production (chicken, pigs, dairy, cattle). Intensive aquaculture around Ho Chi Minh City, Bangkok, Yangon and Phnom Penh.

Water management: Irrigation of horticultural crops, sourced mainly from small-scale pumping from rivers and groundwater. Potential problems of surface-water and groundwater contamination from urban and agricultural pollution.

Uplands

Farming systems: Paddy rice cultivation, with small-scale irrigation in the valleys. Rainfed upland crops, such as maize, cassava and soybeans. Shifting cultivation. Extensive grazing of livestock in forests. High dependence on forest products. Expanding plantations (rubber, coffee) in Lao PDR, Vietnam and Myanmar.

Water management: Limited development of irrigation; mainly small-scale gravity-fed systems for paddy in river valleys. Conservation agriculture used to help retain water and decrease erosion.



Lowlands

Farming systems: Dominated by wet-season lowland rice, with rainfed sugarcane, maize, legumes, pulses and cassava. Increasing use of irrigation for dry-season crops. Rapid expansion of commercial plantations (rubber, oil crops, timber). Combined rice-fish farming and capture fishing from waterways important for livelihoods, especially in Cambodia, Lao PDR and northeast Thailand. Large livestock herds feed on crop residues.

Water management: Irrigation in lowlands mainly provides supplementary water for wet-season paddy and field crops at the end of the wet season and into the dry season. Large-scale storage for irrigation in Thailand. Pumped irrigation in Lao PDR and Myanmar. Dry season shortages and water conflicts.

Coastal zones

Farming systems: Varied production, including lowland rice, rainfed crops, crop/livestock, plus agro-industrial and tree crops (rubber, oil palm, eucalypt, other pulpwood). Marine fisheries important for livelihoods. Marine / brackish aquaculture is limited in non-delta coastal areas.

Water management: Small-scale irrigation of rice and vegetables from rivers and groundwater. Limited irrigation of oil palm in Thailand. Lowland areas prone to flash flooding, due to short, steep catchments.

Deltas

Farming systems: Dominantly lowland rice, irrigated and rainfed. Some irrigated upland crops in the dry season in Thailand (sugarcane, maize, cassava) and Red River Delta (vegetables, maize). High density of livestock. Brackish-water and freshwater aquaculture.

Water management: All deltas modified with dykes, levees and canals to divert and retain water for agriculture. Water is taken directly from surface rivers and streams. Only Red and Chao Phraya have significant upstream reservoirs.

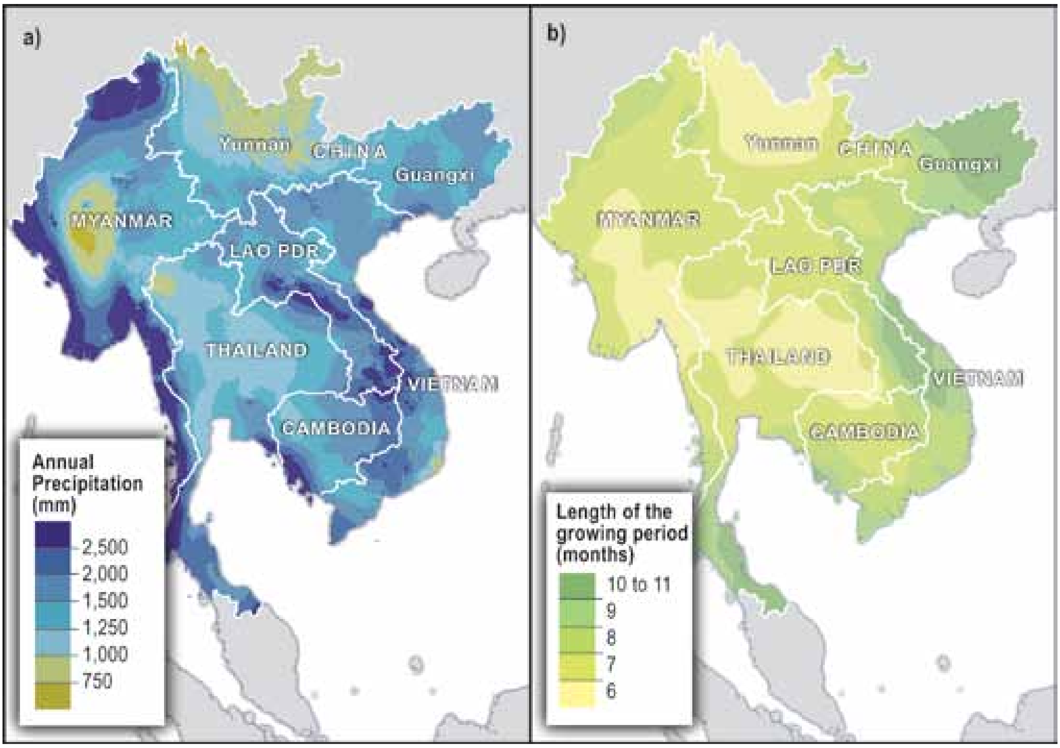
Climatic variation across the GMS

The Southeast Asian monsoon controls climate in the GMS, bringing very marked wet and dry seasons. Spatial and temporal variations in the monsoon define the patterns of rainfed agriculture. The monsoon starts first in the central part of the GMS (Vientiane Plain and central Thailand) in mid-April and commences later in southern Thailand, southern Lao PDR and central Vietnam (late May). The monsoon ends first in northeast Thailand (mid-August) and lasts until early October in Cambodia, southern Vietnam and northern Myanmar.

The driest areas are in central, northern and northeastern regions of Thailand, Yunnan and central Myanmar, with mean annual rainfall ranging between 700 mm and 1,250 mm. The wettest areas, with mean annual rainfall varying between 2,250 mm/year and 5,000 mm/year, include the coastal areas along the Andaman Sea, the eastern coast of the Gulf of Thailand and central parts of Lao PDR and Vietnam (Figure 3a).

Figure 3

The varying environmental conditions across the GMS: (a) annual precipitation; and (b) duration of the growing period for agricultural crops



Areas with the highest rainfall variability include the high rainfall areas along the southern coast of Myanmar, and the lower rainfall areas in central and northeastern Thailand, northern Vietnam and Yunnan. Areas with high rainfall variability are exposed to rainstorms originating from the Indian Ocean, although the variability in northeast Thailand may be due, in part, to storms coming from the South China Sea across north and central Vietnam.

The growing season lasts eight to nine months across much of Vietnam, seven months in most other parts of the GMS and six months in northeast and northern Thailand and parts of Yunnan and Myanmar (Figure 3b). This short wet season is mainly caused by an earlier end to the monsoon in comparison with other areas. The contrast between wet and dry seasons is highest in northeast Thailand, northern Yunnan and much of Myanmar, where the six wettest months contribute more than 90% of the total annual rainfall. The combination of a short wet season, variable onset and high year-to-year variability in total rainfall, make agricultural conditions particularly uncertain in these areas.

Drought in the GMS

Although total annual rainfall across most of the region is high by global standards, drought and water stress are common. There are four main causes of water stress. First, the very strong seasonal influence on rainfall; more than 80% of rain falls during the six months of the wet season and there are correspondingly large moisture deficits during the dry season. Without irrigation, agriculture in the dry season is significantly constrained. Second, the inter-annual variability of rainfall is high. Using the definition of a dry year as being one with less than 80% of mean annual rainfall, drought conditions can be expected between one year in five and one year in 10 over much of the basin (Figure 4).

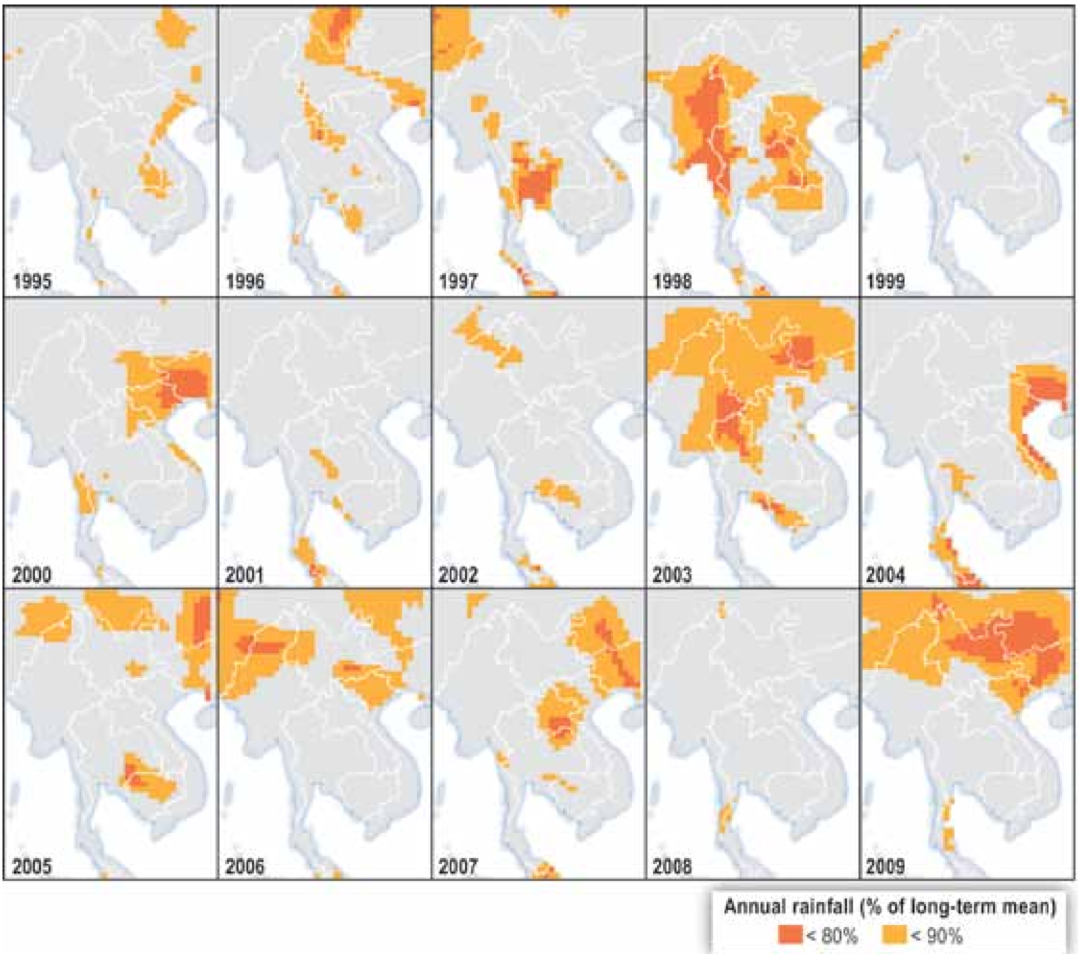
The third, and most common, cause of water stress is changes in the timing of rainfall. For example, drought affected large areas of Thailand and Cambodia in 2004, even though total annual rainfall was close to the long-term average. Almost no rain fell in the last three months of the year, a period that is critical for rainfed rice, resulting in a 30% fall in farm output. Thus, very severe agricultural drought can occur in years where total annual or seasonal rainfall is close to normal (see Box 1, overleaf on page 11).

In the deltas and floodplains, wet- and dry-season cropping depends on the annual flood pulse. In the wet season, overbank flow is needed to inundate the rice crop and in the dry season water is needed for pumped irrigation. Thus, the fourth cause of water stress is when low flows in the river result in hydrological drought and losses.

Flow conditions often bear little relationship to local rainfall, since the majority of flow originates upstream. Low flows in the Mekong in 1998, 2004 and 2009 had significant impacts on production in Cambodia and the Vietnamese delta, where seawater intruded deep into the estuaries as river levels dropped. Flooding and extended inundation can also result in significant crop losses; flooding resulted in major losses in agricultural production in the deltas of the Mekong and Chao Phraya in 2011.

Figure 4

The occurrence of dry years across the GMS between 1995 and 2009. Drought conditions regularly affect farming throughout the region



Box 1

Definitions of drought

Meteorological drought: A period where rainfall is significantly below the long-term average. Precise definitions of meteorological drought are highly region-specific.

Hydrological drought: Depletion of surface and subsurface water resources, usually due to low rainfall, although there may be other contributing factors. Hydrological drought is an important concept in irrigated systems. Meteorological drought in the headwaters of a catchment can result in hydrological drought downstream where local rainfall is normal.

Agricultural drought: A period when soil water is insufficient to meet crop water requirements, resulting in yield losses. Since the impacts of rainfall deficits depend on the types of soils and crops, and cumulative addition and removal in consecutive cropping seasons, agricultural drought can be a very local phenomenon.

Socioeconomic drought: Any situation where water demand exceeds water supply.

Trends in climate

Analysis of past and possible future climate change in the GMS (using long-term records, and regional and global models) indicates a temperature increase of around 0.023 °C/year over the GMS during the period 1960–2049. The highest rates of temperature increase (+0.035 °C/year) are localized in the northern parts of the GMS around north Myanmar and north Yunnan (Lacombe et al. 2012).

There are no strong regional trends in rainfall observed over the past 50 to 60 years, and most regional studies of likely climate change over the next 50 years indicate limited change to the overall amount of rainfall. In general, year-to-year variability is more significant than any observed or projected long-term trends in total rainfall. However, studies do suggest possible future shifts in the seasonal distribution of rainfall, with drier and/or longer dry seasons and shorter, more intense wet seasons, or a delay in the wet season. The latter would have an impact on crops that are sensitive to the daily duration of sunlight.

Even with no change in annual rainfall, the availability of water for agriculture may differ, with increases in the incidence of droughts and floods. There is a high degree of uncertainty around projections of future climate in the GMS, but, at least for the next 50 years, it is unlikely that conditions for agriculture will move much outside the current envelope of variability. The most effective approach to 'no-regrets' adaptation is to work towards greater resilience within the current situation of a highly variable climate, specifically variable rainfall. This will help to improve current livelihoods and at the same time prepare for the predicted effects of climate change.

Rainfed versus irrigated agriculture

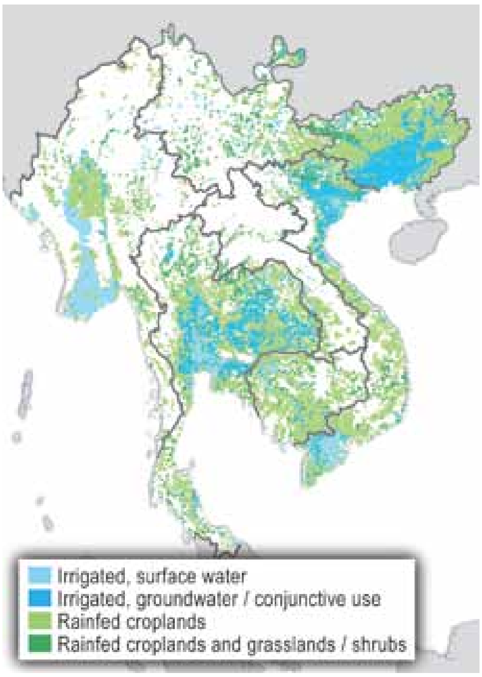
Rainfed agriculture refers to those agricultural systems that are not irrigated and rely solely on rainfall (both directly and indirectly as stored soil moisture) for their water supply. About 80% of the world's farmed lands are rainfed. These systems are sensitive to climate variability, which limits agricultural production. Often, the total amount of rainfall is more than adequate for crop growth, but the variation between years and distribution within the wet season means that droughts and water shortages are common. Floods can reduce productivity or even completely destroy crops.

The proportion of irrigated agriculture in the GMS is increasing over time but is still low in comparison to other parts of Asia. World Bank (2009) reported that between 7% and 35% of total cropland in GMS countries is irrigated, compared to India and Pakistan at 35% and 74%, respectively. Compilation of government statistics for this study indicates that the GMS has a total irrigated area of around 10 million hectares (Mha), or 20% of total cropland (Figure 5).

These statistics, however, mask a more complex picture. While it is acknowledged that the majority of agricultural production in the region is rainfed, determining the relative extent and importance of rainfed production as distinct from irrigated production is surprisingly difficult. First, the dominant crop across the region is wet-season lowland rice, grown in lowland paddy fields under varying degrees of water management, which range from fully rainfed systems to those benefiting from significant amounts of supplementary irrigation. Second, since average annual rainfall exceeds 1,000 mm over more than 90% of the GMS, a significant proportion of water available to the crop comes from rainfall, even in areas where irrigation infrastructure is provided.

Figure 5

Rainfed and irrigated agriculture across the GMS. ***Source: IWMI 2007***



Dry-season crops are usually planted to take advantage of either the beginning or end of the wet-season rains, or of residual soil moisture. More than half of Cambodia's reported dry-season crop is actually recession rice, harvested in April to May but watered primarily from receding floods; Myanmar has a similarly large proportion of recession rice. In the Mekong Delta, two irrigated dry-season crops a year have progressively replaced traditional wet-season rice. However, both receive a significant amount of rainfall. Based on a water account (an analysis of the uses, depletion and productivity of water within a river basin), Kirby et al. (2010) estimated that in Cambodian and Vietnamese subbasins in the southern Mekong Basin, more than 60% of total evapotranspiration from irrigated crops is derived from rainfall.

In many areas, only a small proportion of the land equipped for irrigation actually receives water during the dry season; wet-season supplementary irrigation is much more widely used. In northeast Thailand, dry-season cropping intensity equates to only 10 or 15% of irrigated area. This is attributed to poor reliability of water supply, high labor costs and relatively low returns to the farmer.

In Cambodia, the poor uptake of dry-season irrigation is partly due to a lack of flexibility in the way irrigation water is delivered. The irrigation systems were designed primarily for rice production and do not provide appropriate water control for other higher value dry-season crops. In Lao PDR, the 70,000 ha of irrigated land used during the dry season is only 40% of the area reported as being equipped for irrigation. Conversely, the 162,000 ha of land reported as using some irrigation during the wet season equates to 130% of the formally equipped area, indicating a much more enthusiastic uptake of wet-season supplementary irrigation than full dry-season irrigation. Box 2 outlines the different locations and water-management methods used in rice production.

Box 2

Lowland versus upland

The two definitions commonly used to classify rice production relate to topographic position in the landscape and modes of rice cultivation. Both definitions use the same terms - 'lowland' and 'upland' - but the two definitions are not universally consistent.

Topographic lowlands are flat, low-lying areas generally inundated during the wet season. Uplands are at higher elevations and usually sloping, from gentle to steep.

Lowland rice, whether rainfed or irrigated, is grown under inundated conditions for at least part of the crop cycle, typically in bunded paddy fields. Upland rice is grown in non-inundated fields. Sometimes, lowland rice is grown in upland areas in irrigated valleys and terraces. In this study, the term 'montane paddy' is used for inundated rice cultivation in upland areas.

Similarly, it is possible to have 'upland' (non-inundated) crop areas within lowlands that are dominated by inundated 'lowland' rice. These cropping areas result from very small differences in elevation and water management. 'Upland' (non-inundated) crops can also be grown in topographically low areas at different times from the main wet-season inundated rice crop.

Assessing the suitability of crops to local conditions

There are many factors that affect the suitability of different crop varieties to particular locations. The bioclimatic suitability – the suitability to temperature and rainfall regimes – is a major driver, although other factors, particularly soils, also have an important influence. Differences between the suitability of crops that can be grown and those actually being cultivated by farmers relate to the requirements and preferences of the farmer, the availability and nature of markets, and the suitability of other crops. It is quite common to find that a crop highly suited to a particular area is not grown because other, less favorable crops with a higher demand are grown. Similarly, crops may be grown in areas they are not well suited to because their combined suitability and demand exceeds that of other crops.

The International Center for Tropical Agriculture (CIAT) has developed a simple model based on the Food and Agriculture Organization of the United Nations (FAO) database of crop ecological requirements, called Ecocrop (http://ecocrop.fao.org/ecocrop/). The various temperature and precipitation thresholds from the Ecocrop database are used, or modified by the user, to evaluate the suitability of a certain place for a particular crop species based on a database of global climate data. The main use of the model has been to predict the suitability of various crops under different climatic conditions, and thus at different locations.

The Ecocrop model uses parameters including minimum and maximum temperatures and rainfall for crop growth, and length of the growing season, to assess the suitability of a plant species to a particular location or environment. However, the results must be interpreted carefully. The main limitation is that it is based purely on bioclimatic variables. Although these are extremely important for plant growth and productivity, such a suitability rating ignores specific soil requirements, problems of pests and diseases, and how these factors interact with climate.

For example, the upper and lower limits for rainfall are affected by soil type in terms of the soil water-holding capacity at the dry end of the scale, and infiltration rates when waterlogging is a risk; both of these are further affected by topography. Another issue with the model is that specific varieties or accessions may have slightly different climatic requirements to those in the FAO database. The Ecocrop database has been developed and modified over many years and users can further modify the parameters if they have better information concerning species and varieties.

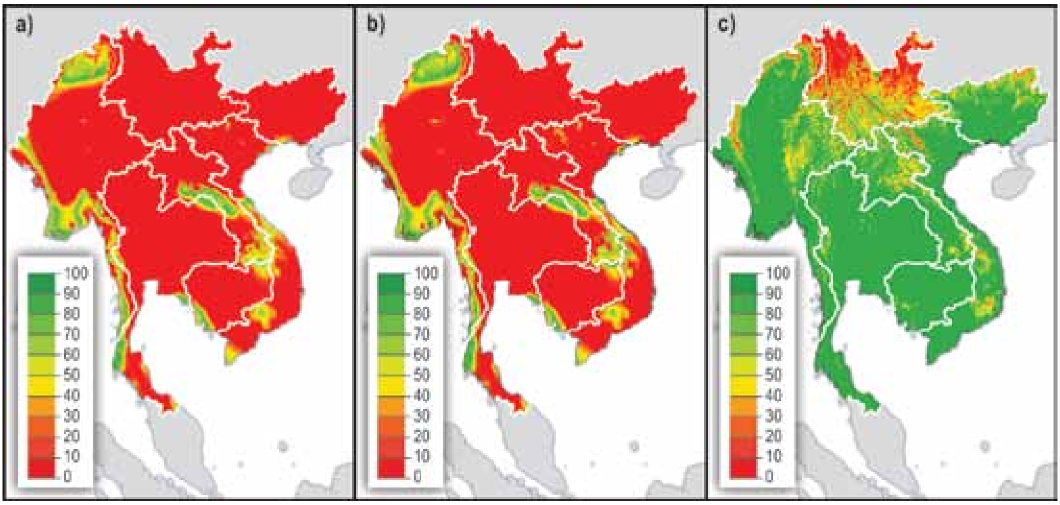
Scientists used the Ecocrop model to assess suitability to conditions across the GMS for a wide range of annual and perennial crops. The parameters were taken from the FAO Ecocrop database, although some modifications were made based on local and expert experience. The crops evaluated include: paddy and upland rice, maize, cassava, kenaf, sugarcane, rubber, oil palm, Arabica and Robusta coffee, peanut, soybean, common bean, cabbage, chili, garlic, mung bean, coconut, banana, pineapple and sweet potato. A suitability map for each crop was created, along with separate maps showing suitability to temperature and precipitation. This enabled the researchers to assess the comparative sensitivity to these two factors. Selected findings from this research are presented here.

Paddy rice

The map of the overall suitability of Indica-type paddy rice (Figure 6a) indicates that most of the GMS is not highly suited to cultivating paddy rice, despite the fact that it is widely grown across the region. As Figure 6b shows, the problem lies with the region's rainfall regime; temperature is not generally an issue, as Figure 6c indicates. Farmers overcome the issue of variable or unpredictable rainfall by employing various methods of water management. The apparent lack of suitability is because the Ecocrop model cannot take into account all of these water-management practices, which include the topographic location of fields, bunding, development of a hardpan to reduce percolation, direction of water flow into and between bunded fields, and anything from supplementary to full irrigation. Where farmers are able to effectively manage water supplies, the suitable temperature regime makes paddy rice a favored crop.

Figure 6

The suitability of Indica-type paddy rice to environmental conditions across the GMS: (a) overall suitability; (b) suitability to precipitation; and (c) suitability to temperature (0 = not at all suitable; 100 = totally suitable)



Results from the Ecocrop model emphasize the high sensitivity of paddy rice to water availability and the need for good water management, which is something that many farmers in the region are not able to achieve. While there are some very productive lowland rice systems that are assured of a good water supply throughout the season from either rainfall or irrigation, there are many marginal rainfed lowland rice systems with a high risk of receiving insufficient or too much water for a good yield.

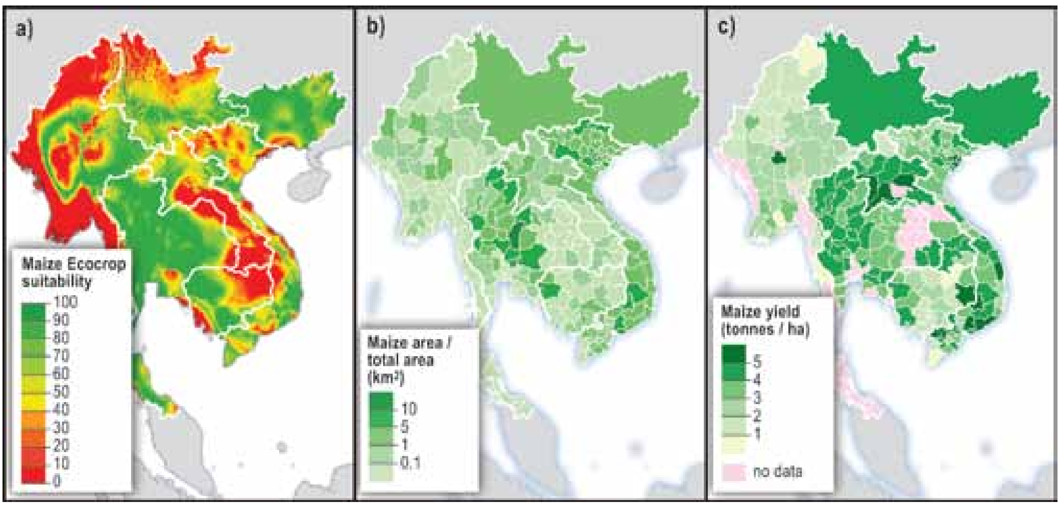
Maize

As with paddy rice, the suitability of maize is driven by the precipitation regime. Here, areas indicated on the overall suitability map as being favorable for growing maize (Figure 7a) more closely match those locations on the ground where farmers are growing the crop (Figure 7b). In Lao PDR, the major maize production belt that lies across the north of the country, in Xayaburi, Houaphanh, Oudomxay and Luang Prabang, is in the zone of highest suitability according to Ecocrop. In most of Thailand, suitability for maize is high and it is widely grown across the country. However, the sandier soils of the northeast are less suitable than areas with better soils in the central and north zones of the country. This is reflected in lower yields in the northeast (Figure 7c).

Clearly, management of soils, especially management of soil organic-matter, and the possibilities for supplementary irrigation, are important factors in maintaining the productivity of maize under variable rainfall regimes.

Figure 7

The suitability of maize to environmental conditions across the GMS: (a) overall suitability (0 = not at all suitable; 100 = totally suitable); (b) the areas in which it currently grows; and (c) the spatial variation in maize yields



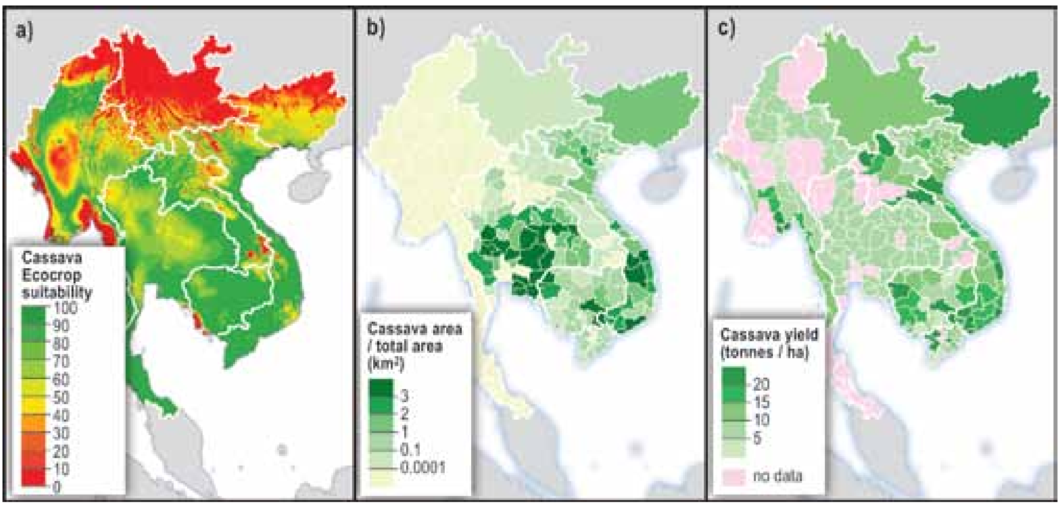
Cassava

In contrast to rice and maize, the suitability of cassava is driven by both temperature and precipitation, (Figure 8a). Temperature is the main restriction in the northern areas, especially in Yunnan and Guangxi, and in certain higher altitudes, such as in northeast Lao PDR. Selection of cool-tolerant varieties is under way in Lao PDR, with some improvement found over the current varieties. However, yields remain quite low. There is much interest in advancing a breeding programme for cold tolerance of cassava in China, where currently at least 60% of production is in Guangxi, mostly in southern Guangxi. Developing new varieties that can thrive in cooler temperatures could allow significant expansion of production into northern Guangxi and other provinces.

Too much and too little rainfall make certain areas unsuitable for cassava. Suitability is low, for example, in coastal Myanmar due to the high rainfall, and suitability is reduced markedly in the dry zone of central Myanmar and parts of north and northeast Thailand due to low rainfall. The area around Nakhon Ratchasima, northeast of Bangkok, is one of the major cassava-producing areas (Figure 8b), despite low suitability and relatively low yields (Figure 8c). This is because cassava is more suitable than many other crops, when the high variability of rainfall and sandy soils are considered. The predicted bioclimatic suitability of maize is greater than cassava in these areas, but the lower fertility of the soils and the higher risk of drought make cassava a more favorable option. This example demonstrates that although the Ecocrop database is useful for predicting crop suitability, the findings need to be modified using local knowledge of rainfall patterns and characteristics of soils.

Figure 8

The suitability of cassava to environmental conditions across the GMS: (a) overall suitability (0 = not at all suitable; 100 = totally suitable); (b) the areas in which it currently grows; and (c) the spatial variation in cassava yields



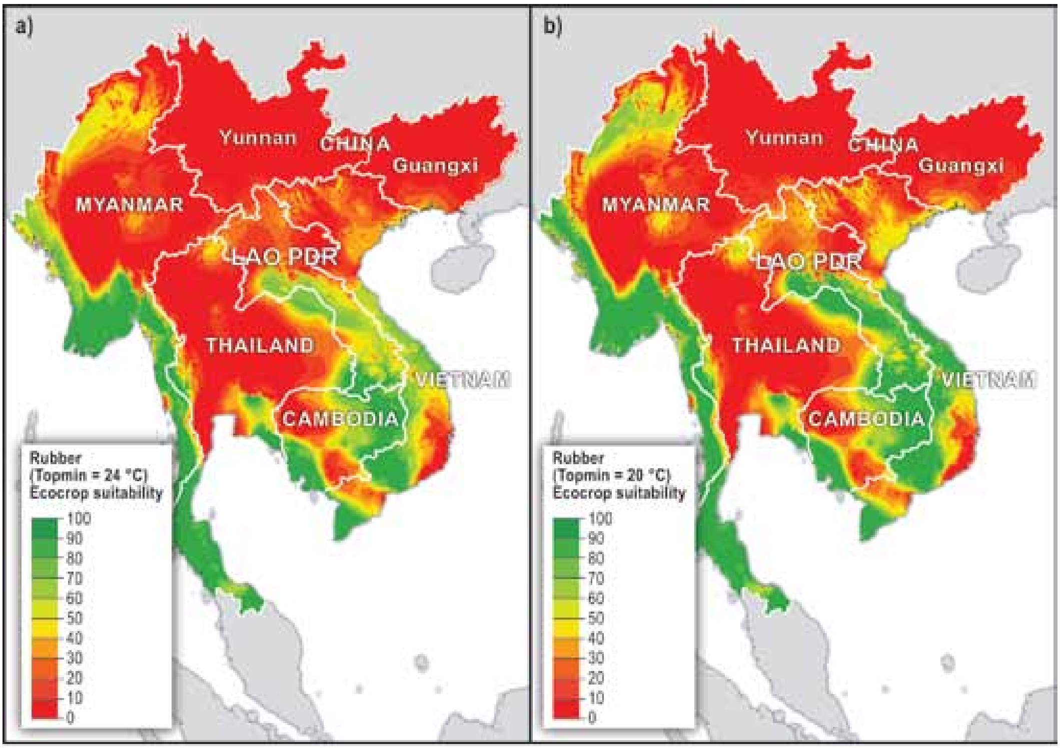
Rubber

The traditional areas of rubber production, in southern Thailand and along the south and coastal areas of Myanmar, are highly suitable. Recently, however, rubber production has shifted into new areas in Kayah State and Magway Division in Myanmar, northeast Thailand, eastern Cambodia, southern and northern Lao PDR, and Yunnan. The newer areas of production in Thailand and Myanmar are more marginal on the basis of the rainfall regime, so yields are lower and soil management is more critical. These disadvantages are compensated for by high local demand. The major constraint in northern Lao PDR and Yunnan, meanwhile, is low temperature. New cool-tolerant varieties, for which 20 ^{0}C is the minimum temperature for optimal growth (Topmin), have been developed to increase the extent of suitable areas. As Figure 9 illustrates, the cool-tolerant variety appears better suited across southern Lao PDR, eastern Cambodia and parts of northern Vietnam and Myanmar.

Assessing the suitability of crops using the Ecocrop model can help agriculturalists better understand and plan well-managed cropping and farming systems. This is critical to improving integrated rainfed agricultural systems; it could particularly benefit more marginal and poorer upland communities.

Figure 9

The suitability of rubber across the GMS for: (a) a variety with standard temperature tolerance; and (b) a cool-tolerant variety (0 = not at all suitable; 100 = totally suitable)



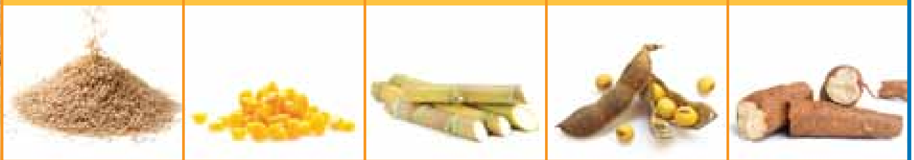
Potential for closing 'yield gaps'

'Yield gap' is the difference between the actual yield achieved on farm and that achievable under the best-known management practices. Various physical, economic and social constraints mean that potential yields are rarely achieved under farm conditions. Factors contributing to yield gaps can be biophysical (climate, water stress, soil, pests), technical (tillage, crop varieties, nutrients), socioeconomic (farmer traditions and knowledge, ability to invest), institutional (relating to land tenure, credit, markets) or related to technology transfer. Reducing yield gaps effectively may require strategies that address several or all of these factors.

Estimates for potential yields of the major regional crops are given in Figure 10. These represent approximate maxima that can be achieved under experimental conditions, and are provided to give a sense of where GMS production currently lies, and where the largest potential gains could be made. Actual potential yields vary between regions depending on soil type, climate and ecology. In some systems, water availability is a dominant constraint on production, but water stress is only one factor contributing to

Figure 10

Potential and actual yields of major crops. ***Sources: FAO 2011 (actual); Peng et al. 1999 - Rice, Pixley et al. 2006 - Maize, Inman-Bamber et al. 1998 - Sugarcane, CIAT - Cassava (potential)***



	Yield (tonnes / ha)									
	Rice		Maize		Sugarcane		Soybean		Cassava	
	2009	1990	2009	1990	2009	1990	2009	1990	2009	1990
Cambodia	2.8	1.3	4.3	2.0	27	43	1.5	1.5	22	5.5
China (all)	6.6	5.7	5.3	4.5	68	59	1.6	1.5	16	13.9
Lao PDR	3.6	2.3	4.8	1.8	31	27	1.5	0.8	14	12.8
Myanmar (FAO)	4.1	2.9	3.6	1.5	47	40	1.5	0.8	13	9.6
Thailand	2.9	2.0	4.2	2.4	72	49	1.6	1.3	22	13.9
Vietnam	5.2	3.2	4.0	1.6	59	41	1.5	0.8	16	8.9
World	4.3	3.5	5.2	3.7	70	62	2.2	1.9	12	10
Asia	4.3	3.6	4.4	3.3	63	60	1.3	1.3	20	12.9
Southeast Asia	4.1	3.0	3.7	1.8	62	62	1.6	1.1	19	12.4
East Asia	6.6	5.7	5.2	4.6	68	59	1.4	1.5	16	13.9
Potential yield in tropical systems	> 10		> 20		> 140		–		> 35	

yield gaps. The timing and severity of water stress dictate how severe the impact is on yield. Water stress during the vegetative stage has a minor impact if time and water supply permit the plant to recover before flowering. Water stress has a more severe impact when it falls during the reproductive stage.

Since the release of improved varieties in the 1960s, the potential yield for irrigated rice in tropical systems is generally assumed to be around 10 tonnes (t)/ha; the highest reported yields in the region are above 7 t/ha in Thai Binh in the Red Delta and An Giang in the Mekong Delta in Vietnam. Nesbitt (2002) reports that yields of up to 9 t/ha were achieved in small experimental plots in the Cambodian Delta. To achieve these very high yields requires not only full management of water, but also careful management of other agronomic factors, particularly fertilizers.

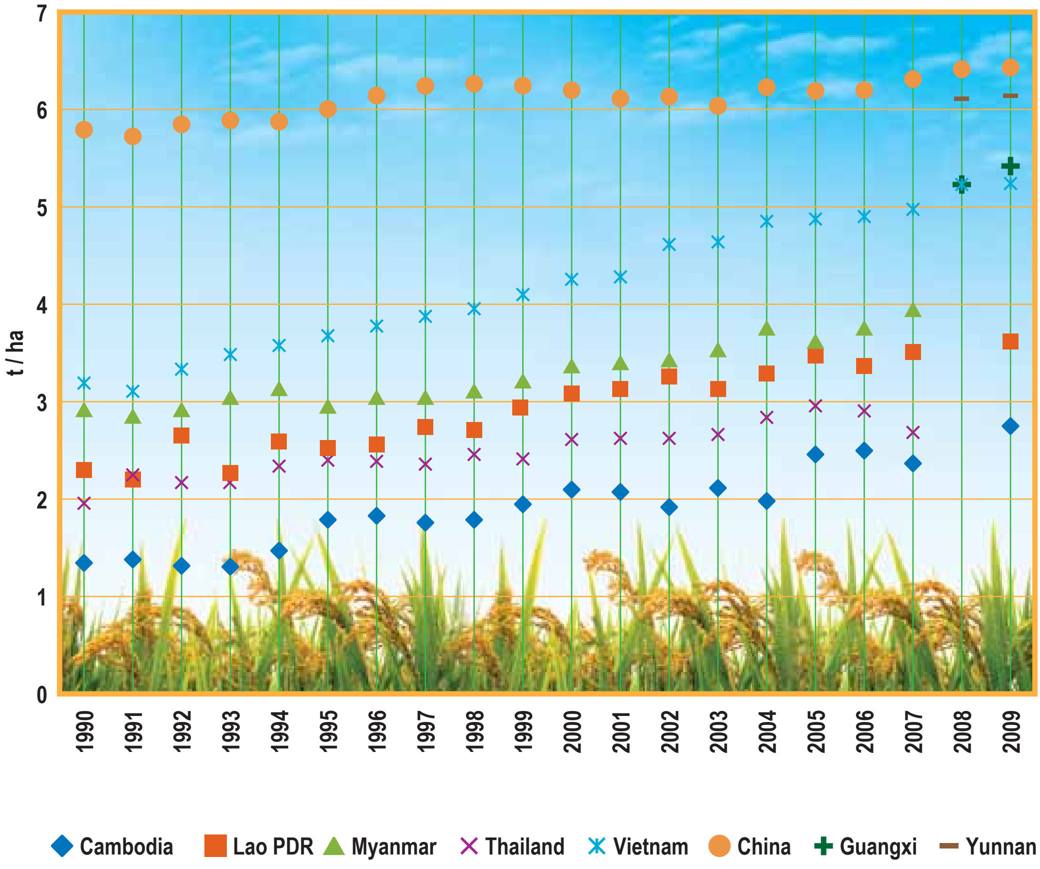
Potential yields for dry (upland) rice are significantly lower. In northeast Thailand, the yield for upland rice under controlled experimental conditions is around 1.5 t/ha. However, yields of up to 3-4 t/ha have been reported for upland rice in northern Lao PDR under shifting cultivation systems. Such high yields can only be achieved after long fallow periods, as yields are very sensitive to the length of the fallow period and cropping cycle. Reported yields decreased to 1.5 t/ha or less when the fallow period was shortened to three years, due to declining soil fertility and increased weed pressure. Significant gains can be made in yields of upland rice, even without irrigation, by carefully controlling soil fertility, weeds and water in well-managed rotations. With a shift from dry rice to montane paddy, yields can more than double, with production per unit area increasing by an order of magnitude or more over a number of years, when the time for fallow for upland fields is taken into account.

National and provincial trends

There have been steady increases in agricultural production within all sub-sectors and all countries of the GMS over the past 20 years. Production in major commodity groups, including rice and small livestock, has more than doubled since 1990 (Figure 11). Approximately 1.5 Mha of new croplands have been brought into production, but much of the observed increase in output has been achieved by intensifying cultivation, rather than expanding the agricultural area. Increased yield is attributed to the adoption of technologies underpinning the 'Green Revolution': improved crop varieties, more effective irrigation, increased use of fertilizers and improved farming practices.

Figure 11

Yields from rice crops are rising across the GMS. *Source: FAO 2011*

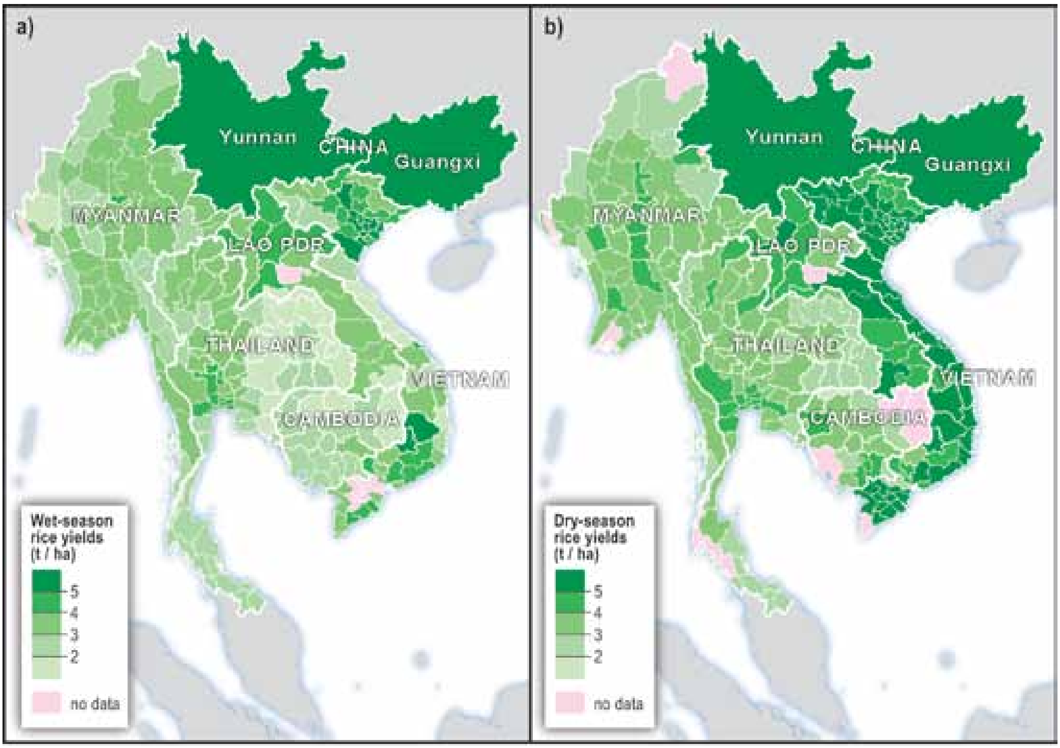


At the national level, there are three main trends related to yields: significant increases in yields for all countries; large differences in yields between and within countries; and large remaining yield gaps. For the GMS, excluding Yunnan and Guangxi, the increase in rice yields, averaged across all seasons over the last 20 years, is between 50 and 100 kilograms (kg)/ha/year. The largest increase has been in Vietnam and the smallest increase in Thailand. Statistics for Myanmar vary widely according to different sources. For example, the FAO reported a national average rice yield of 4.1 t/ha in 2009 based on government statistics (FAO 2011), while the United States Department of Agriculture (USDA) estimated an average yield of only 2.4 t/ha with a significant decline over the last 10 years (reported in Dapice et al. 2010). This has been attributed to a wide range of causes, including droughts and crop failures, poverty restricting the ability of farmers to invest in fertilizers and irrigation, underinvestment in agricultural infrastructure, plus market-related issues such as export bans.

In general, yield differences between countries are higher than differences between AEZs within countries. Analyzing spatial patterns of production and yield within countries can help explain the large differences between them (Figure 12).

Figure 12

Wet- and dry-season rice yields across the GMS. ***Source: national datasets (see main report)***



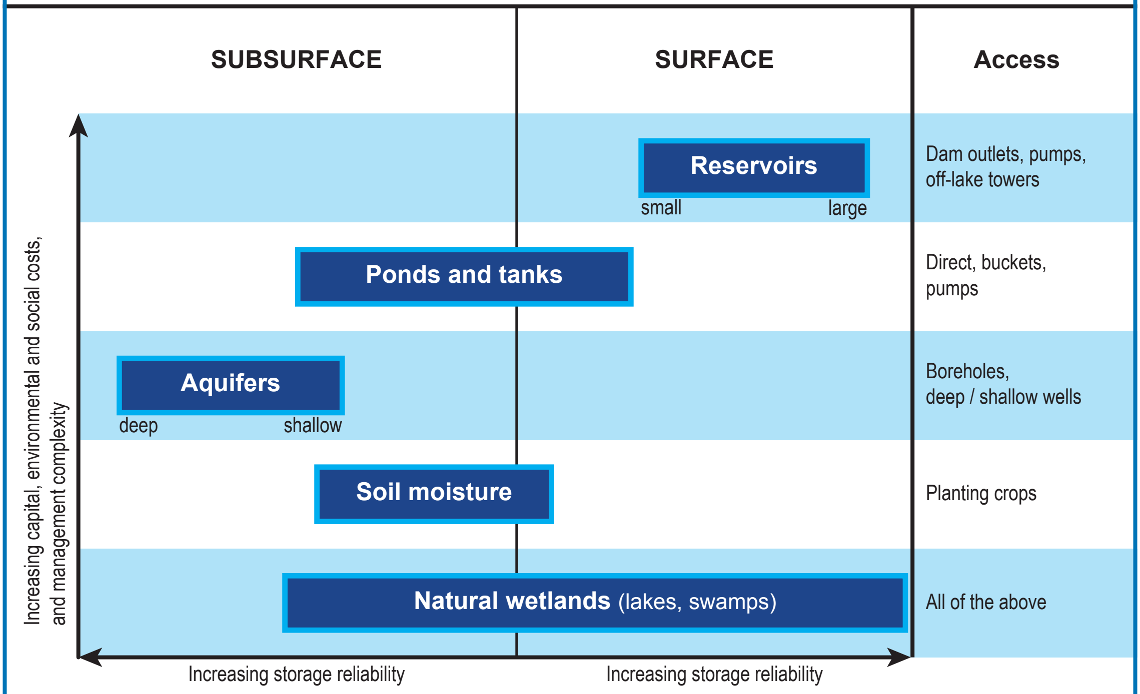
Helping smallholder farmers manage water better

Better water management is an important first step towards improving yields and securing production. Although not necessarily the only or most important constraint to increasing production, access to water is often the least manageable risk factor for smallholder farmers. Where water-related risks are reduced, farmers are more willing to invest in other yield-increasing strategies.

Agricultural water management (AWM) interventions fall into two broad classes: measures to reduce water use or demand on-farm; and measures to control and/or increase water supply through improved storage and transmission. There is a continuum of water storage possibilities at different scales, from soil moisture to major dams (Figure 13). The technologies to improve access to water range from traditional methods, such as treadle pumps, to modern innovations, such as biodegradable plastic mulches.

Figure 13

There is a continuum of water storage options for farmers. ***Source: McCartney and Smakhtin 2010***



Water management must be tailored to specific applications, taking into account the broader context of how water supports livelihoods generally. This context not only includes the physical environment and crop types, but also economics, cultural factors and community dynamics. Interventions that are suitable in the more developed agro-economies of Thailand and Vietnam may not be suitable in Cambodia or

Lao PDR, and vice versa, even under similar physical conditions. Figure 14 outlines some of the choices available for different scales and water sources.

Most importantly, water is only one constraint to agricultural production. To realize the full benefits of decreasing water-related risks, an integrated approach is required, incorporating other factors that affect production, particularly crop and livestock nutrition, value chains and access to markets.

Figure 14

Existing water-management interventions. ***Source: Awulachew S. B. (pers. comms.)***

Scale	Water source	Water control	Water lifting	Conveyance	Application	Drainage and reuse
Smallholder farm-level	**Rainwater**	Soil and water conservation (SWC) In-situ water Farm ponds Cistern / underground ponds Roof water harvesting Recession agriculture	Treadle pumps Water cans	Drum Channels Pipes	Flooding Direct application Drip	Drainage of waterlogging Surface drainage channels Recharge wells
	Surface water	Spate and flooding Diversion Pumping	Micro-pumps (petrol, diesel) Motorized pumps	Channels Canals Pipes (rigid, flexible)	Flood and furrow Drip Sprinkler	Surface drainage channels Drainage of waterlogging
	Groundwater	Spring protection Hand-dug wells Shallow wells	Gravity Treadle pumps Micro-pumps (petrol, diesel) Hand pumps	Channels Canals Pipes (rigid, flexible)	Flood and furrow Drip Sprinkler	Surface drainage channels Drainage of waterlogging Recharge wells
Community or catchment	**Rainwater**	SWC Communal ponds Recession agriculture Subsurface dams	Treadle pumps Water cans	Drum Channels Pipes	Flooding Direct application Drip	Drainage of waterlogging Surface drainage channels Recharge wells
	Surface water	Spate and flooding Wetland Diversion Pumping Micro-dams	Micro-pumps (petrol, diesel) Motorized pumps Gravity	Channels Canals Pipes (rigid, flexible)	Flood and furrow Drip Sprinkler	Surface drainage channels
	Groundwater	Spring protection Hand-dug wells Shallow wells Deep wells	Gravity Treadle pumps Micro-pumps (petrol, diesel) Hand pumps Motorized pumps	Channels Canals Pipes (rigid, flexible)	Flood and furrow Drip Sprinkler	Surface drainage channels Recharge wells and galleries
Subbasin, basin	**Surface water**	Large dams	Gravity Large-scale motorized pumps	Channels Canals Pipes (rigid, flexible)	Flood and furrow Drip Sprinkler	Surface drainage channels Drainage reuse

Identifying the right AWM interventions

Some important and consistent messages have emerged from major programs investigating AWM options internationally; for example, AgWater Solutions project (http://awm-solutions.iwmi.org), the Agwater in Challenging Contexts project (http://challengingcontextawm.iwmi.org) and the 3R Initiative (http://www.bebuffered.com). These can be summarized under the concepts of diversity, context and scale.

Diversity

No single solution will fit the needs of all the farmers in a community. Even within the same cultural, agricultural and ecological system, individual farmers will have their own methods for using the land and water resources they have, and will face different physical and economic constraints. Any solutions will need to be relevant to a range of livelihood choices, and provide technology, price and financing options, so that farmers can make their own choices. Information is as important as hardware.

Context

Water management interventions must be integrated with agronomic improvements for farmers to gain full benefit. The multiple uses of water, beyond agricultural needs, must also be considered when assessing interventions. It is important to leverage water within broader rural livelihoods, taking into account socioeconomic and agro-ecological contexts. Water is inextricably linked to larger landscape processes; by improving water management, it is possible to also improve soil conditions, vegetation cover and micro-climates. Managing water must be seen as part of broader landscape management, taking into account the impacts on other ecosystem components and services.

Scale

Implementation and impacts of AWM interventions cut across scales from field to catchment. The impacts of multiple small-scale interventions can be very important, both economically and ecologically. Opportunities for scaling-up and scaling-out, and the impacts of doing so, need to be carefully assessed.

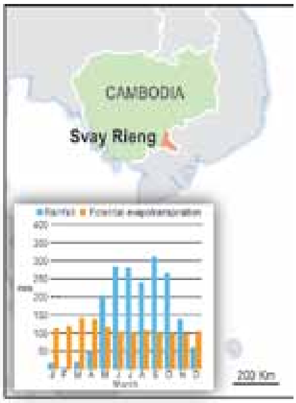
Photo credit: Thuon Try

Potential for using groundwater

There is significant potential for agricultural groundwater use in the GMS. Groundwater irrigation is not extensively developed in the region, compared to South Asia, although the use of shallow tube wells in seasonally recharged alluvial aquifers has increased over the last 10 years. All the region's large river systems have associated alluvial aquifers with mostly unexplored potential for groundwater use. For example, in Cambodia, extensive shallow groundwater reserves exist around the Tonle Sap Floodplains and between the Bassac and Mekong rivers. Water levels in wells follow the river height for distances up to 30 km on each side of the Bassac River, with a lag time of a few weeks, indicating that the aquifers are constantly being recharged.

Aquifers provide both storage (by retaining water longer than in the river) and transmission (since canals or pipes are not required to transport the water as is the case with irrigation directly from the river). Techniques are available to increase the amount of groundwater stored, by enhancing seasonal recharge to groundwater through the use of weirs, check dams and flood spreading. These methods are referred to as Managed Aquifer Recharge (MAR) and can be applied at a range of scales. For example, Lacombe et al. (2005) reported that farm dams in northeastern Thailand maintained water levels in adjacent fields. In Maharashtra, India, groundwater-retention weirs have been constructed to retain and head-up the subsurface flow in rivers, in order to replenish wells upstream of the weir and improve soil moisture (van Steenbergen et al. 2011). On a more ambitious scale, similar technologies are proposed in the Chao Phraya Basin to divert flood flows to extensive shallow alluvial aquifers, which will help mitigate floods and improve groundwater supply at catchment scale (Pavelic et al. forthcoming).

Case study 1: Exploiting shallow groundwater in the Mekong Delta



Location: Svay Rieng, Cambodia
AEZ: Deltas (Cambodian Mekong Delta)
References: Thuon 2011; IDE 2005

Svay Rieng is among Cambodia's poorest and most densely populated provinces. Much of the area is inundated by the annual flood of the Mekong between July and December, which recedes slowly after the end of the monsoon. Low-lying areas are mainly used to grow recession rice, with small areas of irrigated dry-season rice.

In most parts of Svay Rieng, only a single annual crop of rice is grown and is watered by rainfall or receding floodwaters. There is a high risk of failure of this crop; in 2000, 2001 and 2002, the region suffered from floods, while in 2008, 2009 and 2010, it experienced drought. Meanwhile, in 2004 and 2008, there were large losses due to the brown hopper insect pest *(Nilaparvata lugens)*. Access to irrigation would allow farmers to provide supplementary water to safeguard the wet-season rice crop, enable them to be more flexible about planting dates, shift the location of cropping slightly to reduce the potential of flood damage and help them grow a second or third annual crop, especially those with a shorter growing season or higher value.

Svay Rieng has fairly abundant groundwater resources that can be accessed by hand pumps or shallow open wells. In the past, wells were mostly used to provide water for domestic uses. However, in places where groundwater is easily accessible using simple flush bored wells and diesel pumps, there has been a rapid and unregulated expansion in groundwater irrigation. A groundwater-use survey showed that, between 2002 and 2005, the number of domestic hand pumps more than doubled to almost 60,000 and the number of engine-powered irrigation pumps rose from 1,603 to 2,675.

Although farmers using tube wells have reported encouraging results, there are several issues that must be considered if promoting groundwater use. In some areas, there are reports of over-pumping and wells drying out. The potential to exploit groundwater in Svay Rieng is high because there are several confined aquifers within 100 m of the surface. To assess the likelihood and potential severity of local shortages, it is essential to understand the hydrogeology of the area including rates of replenishment, the size of groundwater stores and sustainable limits of abstraction.

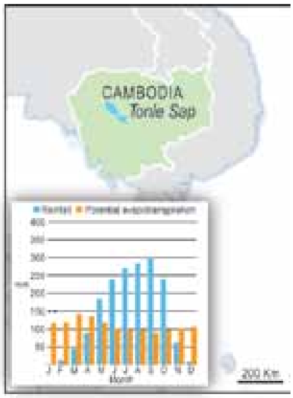
Opportunities for upscaling

The floodplains of the major rivers, both in the deltas and on the lowland plains further upstream, have deep alluvial sequences and offer good prospects for farmers to exploit shallow groundwater resources.

Shallow dug wells and tube wells have transformed irrigation in South Asia by replacing or supplementing large irrigation schemes. There is potential for Cambodia, Lao PDR and Myanmar to 'leapfrog' directly to flexible irrigation systems based on groundwater, without the investment costs involved in large irrigation schemes. However, a thorough assessment of groundwater potential is an essential first step.

Case study 2: The cost of getting it wrong with small reservoirs

Location: Tonle Sap Floodplain, Cambodia
AEZ: Deltas (Tonle Sap Floodplain)
References: DAE 2010; Diepart 2010



The Tonle Sap (Great Lake) in Cambodia is the largest freshwater lake in Southeast Asia and a biodiversity hot spot. In the wet season, the lake fills from the floodwaters of the Mekong, swelling from an area of 5,000 km² to greater than 15,000 km². In the dry season, it acts as a giant retention pond, slowly releasing water to the delta. The flood pulse supports rice-fish systems that are the main livelihood for communities around the lake.

Traditionally, deepwater, or floating, rice was cultivated in the flood zone of the lake, with lowland paddy in higher zones. Canals to provide supplementary irrigation in the wet season were constructed in the early 1970s, but these have now fallen into disrepair. Yields of lowland rice have fallen significantly from 3-3.5 t/ha in the 1970s to around 2 t/ha, due to declining soil fertility. In response, there has been a trend since the 1990s towards cultivating higher-yielding recession and dry-season rice (yields of 3-4 t/ha).

During the late 1990s and early 2000s, small reservoirs with adjacent bunded areas for dry-season rice were constructed on the Tonle Sap Floodplain in several different communes within Kampong Thom and Siem Reap provinces. Between 100 and 150 ha in size, the reservoirs were designed to store wet-season floodwaters for irrigation in the dry season.

On a technical level the reservoirs operated reasonably well, filling the demand for dry-season irrigation to increase crop yields. However, social and environmental outcomes were poor because the reservoirs restricted the formerly common-pool resources of land, water and fish to a small group of wealthier farmers. This angered those who could no longer use the resources and caused conflict within local communities. Cumulative environmental impacts of multiple small-scale developments had serious consequences for floodplain biodiversity and productivity.

In June 2010, the Ministry of Water Resources and Meteorology announced that 30 such reservoirs on the Tonle Sap Floodplain would be destroyed, in order to protect the environment. The Director General of the Fisheries Administration estimated that such reservoirs had devastated around 100,000 ha of flooded forest around the lake, depleting fish stocks.

Lessons for other areas

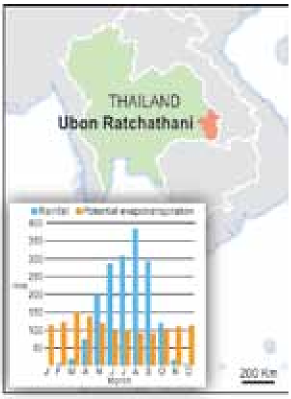
This example emphasizes the need for a thorough assessment of community needs and potential impacts of multiple small-scale developments at different scales to be made prior to implementation. It is important to understand common issues, strategies and problems across different communities and sectors, when setting policies for managing shared zones. A shared vision for managing common-pool resources must be negotiated, taking into account ecosystem links and processes.

Case study 3: Farm ponds improve the livelihoods of farmers

Location: Isan Plateau, northeast Thailand

AEZ: Lowlands

References: Lacombe et al. 2005, Penning de Vries and Ruaysoongnern 2010; Wangkahart et al. 2006



In Isan, lowland rice is the dominant crop, with cassava, sugarcane, maize, vegetables and rubber also grown. Over 90% of rice is grown in the wet season. Farms are mostly smallholdings, with an average size of 2.5 ha per household. Soils are sandy, low in fertility and prone to salinity. Only 10% of annual rainfall comes during the dry season (November to April) and because less than 20% of crops are irrigated in the region, farmers regularly suffer from water shortages.

During the past two decades, there have been initiatives to construct ponds on farms as part of the 'New Theory' of agriculture promoted by King Bhumiphol, to mitigate drought at farm level and promote diversification of crops. Farm ponds typically take up between 10 and 30% of farm area. In 2005, a survey into water use on homesteads was conducted in 130 households in the Buriram, Mahasarakam, Khorat and Yasothon provinces. Ponds were used to water vegetable gardens and orchards, to support livestock and to rear fish. Ponds were also used to provide supplementary irrigation for rice.

Farms with ponds tended to have higher incomes and also produced fish (with significant exceptions). Total income per household, including the value of home consumption, was one quarter less on farms without a pond. Households without a pond produced fewer vegetables and had no surplus to sell; the same applied to animal products. As well as being lower, incomes from farms with no ponds were less diversified than those from farms with ponds, indicating a higher level of vulnerability.

Farm ponds are closely linked to local water tables. Depending on their position in the landscape, farm ponds can act as both recharge and discharge zones for groundwater. Wangkahart et al. (2006) found that lateral seepage into ponds from groundwater was important in maintaining water levels during the dry season; conversely, farm ponds can also provide seepage to increase groundwater recharge. Groundwater and farm ponds can provide complementary water sources at different times of the growing season.

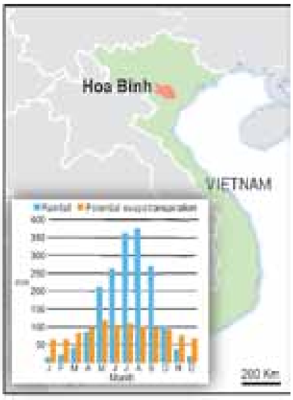
Opportunities for upscaling

Farm ponds offer an effective way to store water from the rainy season for multiple uses during dry spells. Modeling can help answer questions on the optimal size and location of ponds, given information on the local terrain, weather and cropping patterns. In Thailand, existing farmer networks offer a means of communicating findings.

Farm ponds could also provide a cost-effective solution for optimizing performance on small farms in other parts of the globe that have a tropical savannah climate. However, fully assessing the cumulative impacts of many small dams on downstream flows is important, ahead of implementation.

Case study 4: Integrating water management into conservation agriculture

Location: Hoa Binh, Vietnam
AEZ: Uplands / Subtropical highlands
Reference: Mula Rosana et al. 2007



Hoa Binh is a mountainous province with a tropical monsoon climate. The average temperature is 23 °C but this drops to as low as 5 to 10 °C in the dry season. The 789,000-strong population comprises 30 discrete groups, including the Muong (63%), Kinh (27%) and Thai (4%). Around 85% of people live in rural areas. Hydropower from the Hoa Binh Dam contributes almost half of the gross domestic product (GDP) in the region; agriculture, forestry and fisheries contribute around 30%.

Upland farmers in Hoa Binh grow rainfed cassava, maize, sugarcane, fruit trees and agroforestry species, under conditions of sloping land and water scarcity. Soil erosion has had a severe impact on upland farming. Farmers suffer from insufficient water and unstable prices, and poverty rates are high.

As part of the program, 'Participatory Watershed Management for Reducing Rural Poverty and Land Degradation in Semi-Arid Tropical Asia', by the Asian Development Bank and International Crops Research Institute for the Semi-Arid Tropics, a number of interventions were introduced in the Thanh Ha watershed. These were geared at conserving rainwater, reducing land degradation and replenishing soil nutrients through biological nitrogen fixation.

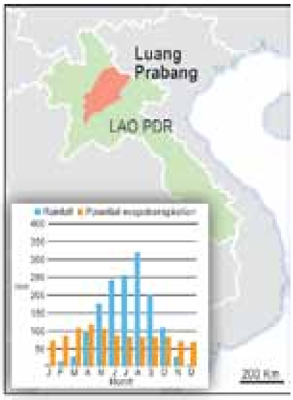
Pits and ponds were introduced to retain water and reduce soil erosion. Conservation agriculture techniques included introducing improved varieties of legume plus watermelon crops; using polyethylene mulching; constructing stone barriers (stone bunds, bench terraces and contours) and supplementary physical structures (pits, contour canals, percolation tanks); and applying micronutrients and *Rhizobia* soil bacteria that fix nitrogen. The introduction of these techniques, combined with the development of ponds, resulted in improved soil structure, reduced runoff and soil erosion, as well as prompting well levels to rise by 1.5 to 2 m. These were complemented by better yields and reduced use of herbicides and fertilizers. Higher income and improved food security (plus access to new foods) has enabled more families to benefit from education.

Opportunities for upscaling

The problems encountered in Hoa Binh, primarily low productivity on steeply sloping lands with high rates of erosion, are common across the uplands of the GMS. Integrated approaches to soil and water management developed and tested in Hoa Binh could be applied across northwest Vietnam, northern Laos and Myanmar in areas with similar topography and farming systems.

Case study 5: Raising yields by introducing montane paddy

Location: Luang Prabang, Lao PDR
AEZ: Uplands
References: Linquist et al. 2007; Souvanthong et al. 2009



In the sparsely populated sloping uplands of northern Lao PDR, traditional livelihoods rely on shifting cultivation (swidden agriculture) of upland rice and other crops, with farmers also dependent on forest products and grazing livestock. Growing populations and government policy to eradicate shifting cultivation, combined with moves to protect forestlands, have limited areas where farmers can grow crops. This has resulted in a shortening of the swidden cycle, causing yields to decline, and increasing food shortages and poverty.

Markets in remote areas of Luang Prabang Province are not sufficiently developed to enable farmers to replace rice with cash crops. To increase rice production in the uplands, the government has developed small irrigation schemes in flat areas of valleys. These usually cover a few tens of hectares. Another response has been for individual farmers or communities to build terraces for montane paddy. Between 1990 and 2002, the area of montane paddy in the northern region of Lao PDR increased by 70%. By 2009, paddy rice (rainfed and irrigated) made up 55% of the total area planted with rice in the northern region.

A survey of villages in northern Lao PDR found that average yields of upland rice in surveyed villages was 1-2 t/ha, compared to yields of 3-4 t/ha for montane paddy. Households with more than half a hectare of paddy did not experience rice shortages in the 10 years prior to the survey, but families with less than 0.1 ha experienced shortages in at least one year in two. The shift to paddy increased the rearing of livestock, important as a source of cash income, and allowed farmers to grow more cash crops on upland fields.

Sloping fields are converted to paddy terraces by moving soil to make flat areas; the greater the slope, the more soil must be moved and the higher the establishment costs. Canals and weirs to provide water for irrigation must also be constructed. Constructing terraces requires a high input of labor, and it takes several years for yields to stabilize on new terraces. However, it only takes around four years to recoup those costs through better rice yields and labor savings. Erosion rates from terraces are much lower than from cultivation on slopes, and higher productivity reduces pressure on existing land and avoids the need to open up new areas.

Opportunities for upscaling

Making more of the flatter lands available for paddy production and intensifying production from the rice paddies, could help reduce pressure on the fragile steep areas. Suitable areas for paddy development are limited, however, so this should not be seen as the only alternative to growing upland rice. Obvious areas for conversion have already been developed, so costs for future developments are likely to be higher. There is often high potential to improve water management and delivery using weirs and canals to deliver water more effectively and, in some cases, expand the area of paddies. Taking a landscape perspective can help achieve an acceptable balance of relatively intensive crop production and land conservation that avoids soil erosion and degradation. However, making the transition requires incentives that will encourage farmers to change their farming practices.

Case study 6: Coping with frequently occurring droughts

Location: Yunnan, China
AEZ: Subtropical highlands
Reference: Caizhen 2011

The Yunnan Province is mountainous, with some peaks in the northwest extending as high as 3,000 m above the valley bottoms. Most farmland is rainfed and sloping, with limited irrigation, especially in the mountains. Although Yunnan is crossed by more than 600 rivers, and has the third highest per capita water resources of China's provinces, it has experienced a warming climate and 12 drought years since the late 1980s. Droughts occurred in 1987, 1988, 1989, 1992, 1993, 1997, 2003, 2004, 2005, 2006, 2007 and 2009, with each drought affecting an area exceeding half a million hectares.

The recent trend has been for severe drought to strike between March and June when most summer crops need water to grow. Then, from July to September, when the crops need sunshine to ripen, there has been too much precipitation. Winter crops have also been affected by drought, between November and March. The main impacts have been loss of agricultural production, reduced drinking water for humans and livestock, food shortages, increased prices of food, energy and industrial items, and reduced volumes of water in reservoirs.

The drought in 2009–2010 was particularly severe. By April 2010, some 3.2 Mha of food crops and cash crops were affected, of which 2 Mha were damaged and over 1 Mha could not be harvested. The direct economic loss exceeded CNY 12 billion. More than three million people lacked food, and large numbers of people and animals had insufficient drinking water. Observing the way in which Yunnan has responded to these droughts provides an opportunity to learn for climatic shifts elsewhere in the future.

Strategies proposed and implemented by local authorities and the Chinese Government for adapting to drought included: converting paddy fields to dryland or alternate wetting and drying management, intercropping and interplanting different types of crops, compensating the loss of winter crops with summer crops, and using plastic film to prevent evaporation; encouraging labor migration; providing anti-drought equipment, such as water pumps, water pipes, diesel engines and plastic buckets, and assistance to dig wells; providing drinking water by truck, water tanker and oxcart to households with no water, from February 2010, after several months of drought; and urging locals to cut down thirsty eucalyptus trees.

Most households responded by diversifying their crop production away from only growing rice. They also reduced their livestock numbers from the usual two or three pigs, sheep or goats to just one for self-consumption. As more people began to sell their animals, the prices fell. Many villagers and households built water ponds, dams, cellars, water jars or tanks. However, many of these dried out during periods of drought. Households tended, traditionally, to store enough rice for one to three years. They also pickled vegetables and preserved meat. Domestic washing was reduced to using a cloth to wash the body and washing underwear but no other clothes.

So, why was there such a big impact from the droughts in a relatively water-rich area, where agriculture is of great importance to economic development? By 2007, 5,403 reservoirs were in place in Yunnan, along with aqueducts and channels for carrying water to paddy fields. However, much of this infrastructure was developed in the 1960s and 1970s and was no longer working effectively. Irrigated area decreased from 45% in 1997 to 36% in 2008, which is much lower than the average in China. Moreover, many of the hydropower stations in Yunnan are designed purely to generate energy, and tend to compete with farming for water in the dry season.

Allocation of water favors urban areas and industry, rather than rural regions and agriculture. During the 2009–2010 drought, around a third of the rural population did not have safe drinking water but urban areas were supplied with drinking water from large reservoirs. Poverty affected 13% of Yunnan's inhabitants in 2007, compared with 1.6% across China as a whole (based on the national poverty line). Poor households had limited resources and income sources to help them cope with the drought. The study concluded that socioeconomic and institutional vulnerabilities were preventing rural inhabitants from adapting and coping in times of drought.

Lessons for other areas

Drought is a common phenomenon across the GMS, particularly in the drier zones of northeast Thailand, Myanmar and northern Yunnan. It hits hardest in agricultural communities without secure water sources. Constructing large reservoirs for urban supply and hydropower does not protect local farmers from the effects of drought. Effective responses to drought must come at the local level. Water-harvesting technologies, such as ponds, small dams and water cellars, are important drought-proofing tools for communities, for providing water for drinking, livestock and crops. Other methods that can help reduce risk include crop diversification, generating off-farm income and farmer insurance.

Focus for the future

A strong defining feature of agricultural systems across the GMS is the rapid pace of change, driven by a complex mix of large-scale forces and unplanned individual land-use choices. For example, in upland Lao PDR, farmers shift rapidly to large-scale planting of maize or rubber in response to external buyers, and a few years later shift again. A common perception is that these changes occur over large areas of land in very short time frames, but neither the proportion of the population engaged in these activities nor the social or environmental impacts are well understood.

In this context, land-use planning has a hard time keeping up with unplanned changes. Resettlement schemes, mining, establishing commercial plantations and constructing hydropower dams also change the conditions and landscapes within which people attempt to secure their livelihoods. Given that farmers often need to shift rapidly in response to external forces, and adjust to new environments and conditions, developing the capacity of populations to adapt and building supporting institutions are high priorities.

Biophysical and economic diversity in production systems is an important part of building resilience at both household and landscape scales. Discussions on sustainability need to encompass how landscapes can function as a whole while supporting a variety of cropping and farming systems. The focus must be on nurturing fundamental ecosystem services that support agricultural production (such as soil fertility, nutrient cycling, water cycling and pollination services) rather than simply assessing the potential for growing individual crops.

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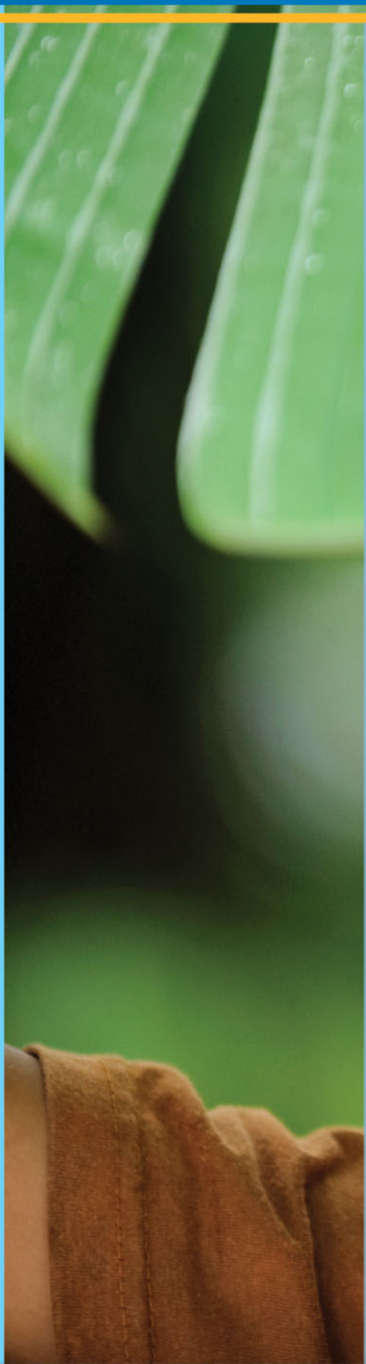

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