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Rainfed agriculture: its importance and potential in global food security

Rainfed agriculture or agriculture without irrigation is extremely challenging. It merits greater attention and investment in R & D because the area of arable irrigated land has reached a plateau globally and is shrinking in many countries.

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The integration of Brahman cattle with oil palm plantations in Kinabalu, Sabah, Malaysia.

Rainfed agriculture is agriculture that is totally dependent on rain. In the absence of irrigation, rainfed lands, especially those in the arid and semiarid agro-ecological zones of the world, have been regarded as *fragile, marginal, waste, problematical, threatened, low potential* or *less-favoured* lands. The term '*less favoured areas*' (LFAs) is better as it is relatively free of negative connotations.

The Green Revolution, which saved Asia from food shortages in the 20th Century, was driven by the development and use of high-yielding rice and wheat varieties, supported by vast irrigation schemes and high fertilizer inputs. However, in large areas of Asia, irrigation is not possible, and in these areas, rainfed agriculture remains a major contributor to agricultural production. The success of the Green Revolution contributed to the neglect of rainfed agriculture, but the continuation of such neglect can have serious consequences. In India, for example, Fan and Hazel (2000) have estimated that 82% of the rural poor live in rainfed areas. Such people are highly vulnerable to climatic fluctuations. If the rains fail, the consequences are crop failure

Table 1. Stages of the Green Revolution in Asia

1950s
- Low rice yields; inadequate food supplies
- Considerable poverty

1960s
- Introduction of new high-yielding cereal varieties, developed through plant-breeding
- Take-off of the Green Revolution, supported by irrigation and fertiliser subsidies

1970s
- Massive irrigation investments
- Increased cereal yields; expansion of cereal lands
- Increased affluence; increased availability of cereal crop residues for animals

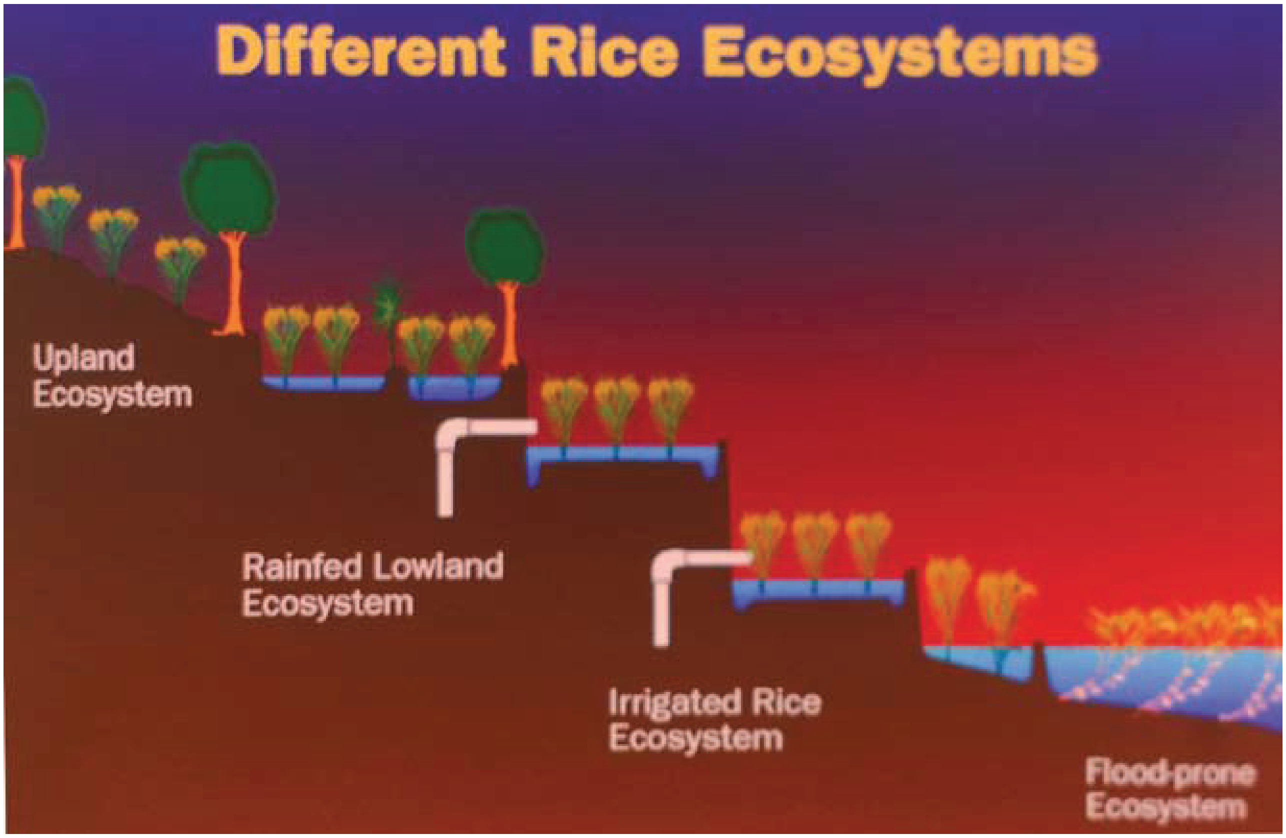
1980s
- Increasing rice yields and affluence
- Self-sufficiency in rice in some countries that were in previously facing critical shortages e.g. Philippines
- Reduced poverty

1990s
- Declining rice yields due to salinity and water-logging, micronutrient deficiencies, lowering of water tables, human health hazards due to pesticide and water contamination and pest build up
- Diminishing returns
- Signs of natural resource degradation
- Recognition of economic disparity between the richer farmers in the irrigated areas and the poorer farmers who have been by-passed by the Green Revolution

2000s (projected)
- Consideration of other ecosystems beyond irrigated areas e.g. rain-fed areas for grain production
- Increase in equity and environmental concerns
- Search for increased production efficiency and ways to increase grain yields, and
- New focus on sustainable and ecological farming systems.

and reduction of feed availability for grazing animals. Households with camels, goats, sheep and cattle would be forced into semi-nomadism and nomadism, and poor people would be marginalized further into extreme poverty. Severe damage to the environment would be inevitable.

Globally, 925 million people are at risk of being pushed into extreme poverty (World Bank, 2011), but it only takes a 1% increase in agricultural productivity to reduce poverty by 0.37%, and take 26 million people out of poverty (ESCAP, 2008). The lack of action to address the problems of rainfed agriculture may be attributed to lack



Rice ecosystems in Asia. Parts of the lowland rainfed ecosystem may benefit from seepage of water from nearby irrigated systems.

of a priority policy framework for rainfed lands and weak understanding of the interactions between food insecurity, poverty, sustainability, natural resources and self-reliance.

The national agricultural research systems of the affected countries have not given priority to R&D to develop technologies for rainfed systems, in particular, to the development of heat- and drought-resistant plants and animals that can cope with environmental shocks. In the absence of a policy framework to give priority to rainfed lands and needs-based and well-coordinated interdisciplinary R&D effort backed by investments, it is unlikely that there will be quantum jumps in progress.

The empowerment of women is also essential so that women can be engaged more effectively in promoting technologically-driven transformation and rural growth.

More attention should be given to rainfed agriculture for many reasons:

- Of the available agricultural land in Asia, rainfed areas account for about 83.1% of land area compared to 16.6% irrigated land. In South East Asia, the total rainfed area is 99 million ha and in South Asia 116 million ha. About 63%of the rural population is found in the former compared to only 37% in the favoured arable areas.

Typical small farmer household in Chulidanda hilly area, Nepal. Note how part of the house is used to store cereal straws for winter feeding, and to serve as a pen to house the goats.

- Arable land for crop cultivation has reached ceiling levels. The total arable land for crop cultivation has plateaued, and is shrinking in many countries.
- Rainfed areas are reservoirs holding large concentrations of ruminants (cattle, goats and sheep), camels and smaller numbers of buffaloes. In Asia, rainfed areas host about 51% of the total cattle and 55% of the total small ruminant population (TAC, 1992). In S. Asia, 70 to 90% of the ruminants (buffaloes, cattle, goats and sheep) are found in rainfed areas and these are often indigenous breeds that sustain much genetic diversity.
- Demand for animal protein supplies for human consumption is increasing. To meet the increased demand for animal proteins, improved productivity will be necessary through intensification and expansion of animal-agriculture.

Biophysical features of rainfed lands

The following features are characteristic of rainfed agricultural areas in the semi-arid, arid and sub-humid agro-ecological zones:

- Average growing period of 120-160 days
- Long dry seasons occasionally with extended droughts.
- Nutrient-poor soils.
- Populated by small farmers and landless people engaged in subsistence agriculture.
- Mixed farming of annual and perennial crops (millets, sorghum, oilseeds, cotton, rice and wheat) is the norm.
- Crop failures occur from time to time due to water scarcity.
- Crop cultivation is dependent on manure from animals but overstocking of animals is common and this results in overgrazing.
- Overgrazing contributes to loss of bio-diversity, decline in C sequestration, reduced water availability, and desertification.

Table 2. Distribution of land types (% of total land) by region (CGIAR/TAC, 2000)

Region	Favoured	Marginal	Sparsely populated arid lands	Forests and woodlands	Rural population living in favoured lands (%)
Asia (excluding West Asia)	16.6	30.0	18.5	34.6	37 .0
Latin America and the Caribbean	9.6	20.3	8.1	61.9	34.0
Sub-Saharan Africa	8.5	23.1	24.6	43.7	27.0
West Asia and North Africa	7.8	22.6	65.8	3.9	24.0
Total (105 countries)	10.7	24.0	25.9	39	35.0

In South East Asia the rainfed area as a proportion of total agricultural land ranges from 63% in Indonesia to 68.5% in Malaysia and 97% in Cambodia. In South Asia, the corresponding values are from 27% in Pakistan to 84% in Nepal. Only in Pakistan and Sri Lanka does the percentage of irrigated land exceed that of the rainfed area. In absolute terms however, the largest irrigated land area, of 43.8 million ha, is found in India. The contributions of rainfed production, excluding Pakistan, to agricultural gross domestic product ranges from 16% in Malaysia to 61% in Myanmar. Most of the farmers in rainfed areas are small farmers or smallholders and the landless, and farm sizes are very small (Devendra, 2010).

In Malaysia, both annual and perennial crop production are prevalent. While rice, fruit, pepper and vegetable production is important, the tree crops (oil palm, rubber and cocoa) dominate agriculture, involving both large plantations and small farmers. The tree crops occupy more than 86%of the total agricultural area and involve most of the fertile alluvial coastal plains and undulating foothills. Oil palm alone uses about 63.4% of the total agricultural area, followed by rubber. The land area is further expected to expand by about 2% by 2010.

Rainfed farming systems

Farming systems are determined by the biophysical environment, notably irrigation, rainfall, water and soil quality. Most of the arid and semi-arid, and a significant proportion of the sub-humid zones occur in South Asia. Most of the humid and sub-humid lowlands are found in South East Asia. The lowlands and uplands are a continuum, with the former having greater opportunities for crop cultivation because of increased soil moisture and less fragility. The lowlands have larger areas of arable and permanent cropland, which account for the greater crop production in these areas.

Table 3. Extent and importance of rainfed agriculture in selected countries in Asia (ADB, 1989)

Selected countries	Total rainfed area in 10^6 ha	Rainfed area as a proportion of total arable land (%)	Rainfed production as a proportion of agricultural GDP (%)	Population dependant on agriculture (%)
East and S.E.Asia				
1. China	52.0	53.8	33.0	30.0
2. Indonesia	9.2	62.2	19.1	36.8
3. Thailand	13.8	81.6	49.9	59.4
4. Vietnam	4.4	53.8	33.0	30.0
S.Asia				
5. Bangladesh	7.7	81.6	40.5	41.5
6. Bhutan	0.07	81.0	28.9	93.0
7. India	100.0	69.5	25.7	43.2
8. Nepal	2.6	84.0	40.9	41.0

Using the classification of the Technical Advisory Committee TAC (1994) of the CGIAR, the rainfed agro-ecological zones of relevance are as follows:

- Rainfed temperate and tropical highlands—mainly the Hindu-Kush/Himalayan region.
- Rainfed humid/sub-humid tropical systems—mainly countries in Indo-China, South East and East Asia, and the Pacific Islands, and parts of South Asia particularly Bangladesh and Sri Lanka.
- Rainfed arid/semi-arid tropical systems—mainly countries in South Asia excluding Nepal and Bangladesh.

Rice is the dominant crop in Asia, and produces variable yields in the range of 1.5–3.0 t/ha. Pulses and oil seeds are also grown. Buffalo populations are lower in the rainfed than in the irrigated areas, and the reverse is true of cattle.

In the uplands the topography is hilly and often with steep fragile slopes. Overgrazing and resource degradation is common. Both annual (cereals, legumes, roots and vegetables) and perennial crops (coconut, oil palm, rubber and fruit trees) are grown, often without integration with animals. Rice yields are in the range 0.9 to 1.6 t/ha. Lower populations of cattle, goats and sheep, but high populations of pigs and poultry are common.

In rice ecosystems, four categories are identifiable. The areas immediately outside the irrigated areas have the benefit of water seepage and spill-over from the irrigated areas. These areas are very useful to plant growth which of course will also produce reasonable yields. Unfortunately, no statistics are available on the extent of this area, but it is quite sizeable.

Table 4. Some household attributes and biophysical characteristics in rainfed farming systems in five countries in South East and East Asia (Devendra, 2005)

	Vietnam	Thailand	Indonesia	Philippines	China
Household attributes					
Average farm size (ha)	2.59 +/- 1.97	5.24 +/- 2.74	0.55 +/- 0.73	1.26 +/- 0.45	0.27 +/- 0.12
Household size (persons)	4.94 +/- 1.74	4.79 +/- 2.08	4.46 +/- 1.54	5.52 +/- 2.33	4.73 +/- 1.29
% of farms managed by women	28.4	31.6	4.2	30.0	26.0
Biophysical attributes					
Location	Dong Tam, Bin Phuoc	AmphurMuang Mahasarakham	Dangiang, Cilawu, Garut	Don Montano, Umingan, Pangasinan	Bixi Xiang, Nanjian, Yunnan
Mean annual rainfall (mm)	2,170	1,500	2,200	2,300	760
Dry season (months)	6	6-7	5-6	6	7
Farming systems					
Predominant crop-animal systems	Rice-based beef cattle production	Rice-based dairy cattle production	Rice-based cattle fattening and sheep raising	Rice-based beef cattle and goat production	Wheat/maize-based beef cattle and goat production
Predominant animal species[1]	BC, Pi, Po	DC, Pi, Po	BC, Bu, S, G, Fi	BC, Bu, G, Pi, Po	BC, Bu, G, Pi, Po
Number of animals (TLU's)	0.67 +/- 1.69	7.34 +/- 4.32	0.70 +/- 0.78	2.26 +/- 1.97	1.07 +/- 0.73
Main crop-animal interactions	Crop residues as feeds, use of draft animals	Crop residues as feed, manure as fertilizer, use of draft animals	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizers, use of draft animals
Contribution of livestock to total income (%)	13	10 - 20	10 - 15	15 - 20	20 - 25

BC =Beef cattle, DC =Dairy cattle, Bu =Buffaloes, S=Sheep, G =Goats, Pi =Pigs, Po =Poultry, Fi =Fish.
TLU =Tropical livestock unit, equivalent to a ruminant animal of 250 kg body weight. Only ruminant species have been considered for its estimation, according to the following equivalencies: cattle and buffalo =1.0, sheep and goats =0.01; in all species, mature male =1.0; mature female =0.75, growing animal =0.5; pre-weaned animal=0.2

The food-feed system is an important strategy. Photo shows farmer with cowpea- cassava system to benefit both household consumption and feed for animals in Mahasarakam, North East Thailand, similar to rice-siratro-mungbean cropping system in the Philippines.

Emphasis should be given to such areas because they should be able to support relatively high crop yields.

Table 4 gives some indication of the household characteristics, bio-physical data, and patterns of farming systems on five rainfed locations in China, Indonesia, Philippines, Thailand and Vietnam . The key features are as follows:-

- Average annual rainfall of 1,500–2,300 mm.
- Rice-based cropping systems are common, but also includes other annual crops and tree crops.
- Both ruminants and non-ruminants are reared, and the presence of both animal and crop diversity provides a variety of crop-animal interactions (Devendra & Thomas, 2002).
- The overriding major constraint is the 5 to 7 months of dry periods.
- There is a 10 to 25% level of contribution by animals to total farm income (Devendra, 2005).
- The ownership of animals is especially important for sustaining livelihoods and survival.

Pathways for increasing food production

Several definitions of food security exist, but that of the FAO (2003) is noteworthy: *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food for a healthy and active life"*.

Typical lowland and upland continuum in Chulidanda hilly area in Nepal.

Increasing food production in the future is linked to three possible pathways:

- Increasing the area of arable land.
- Intensifying the use of existing arable land, and
- Expanding production in the less-favoured areas.

The prospects for significant increase in the area of arable land are low. Arable land is being lost to urbanization, which involves the conversion of lands, often fertile arable lands, to housing, recreation, industrialization and resettlement schemes, roads and railways.

Another problem of increasing concern is fragmentation of farm holdings. In China for example, the available arable land has decreased from 130.04 million hectares in 1996 to 103.03 million hectares in 2005. Associated with this, *per capita* arable land has fallen below 0.094 ha in 2004 (Qiu *et al*., 2008). A similar situation also exists in Indonesia. If the process of land fragmentation continues, farmers will have to shift out of agriculture.

The intensification of use of existing arable lands, including intensive peri-urban poultry and pig production, comes with growing environmental concerns and health risks from agrochemicals.

Of equal concern is the loss of about 5.7 million hectares of arable land annually through soil degradation, and a further 1.5 million hectares as a result of water-logging, salinization and alkalization (FAO, 1999).

Hence expanding production in the rainfed areas should deserve more attention. However, in the face of climate change, land use systems

Dung from ruminants is the main source of fertiliser in small farms. Photo shows small amounts of dung dispersed in rainfed areas of Chulidanda, Nepal, awaiting ploughing using cattle to cultivate the rice field.

especially in the semi-arid and arid agro-ecological zones will come under great pressure and are likely to be associated with the following problems:

- Increase in variation in the quantity and quality of vegetative growth and yield,
- Increase in overstocking of animals as a means to reduce economic risk,
- Loss of vegetative cover,
- Soil erosion,
- Contamination of underground water due to excessive use of pesticides and fertilizers,
- Desertification.

Water is essential for agriculture but agriculture has to compete with human and industrial needs for water. During the long dry seasons in parts of South Asia, water shortages are very common. Mobs of people have to chase water trucks that come twice a week to supply the people. As it is, agriculture is being criticized for using too much water. At the International Rice Research Institute in the Philippines, it has been reported that to produce 1 kg of rice, 4,700 litres of water are required; which is a huge input (Lampe, 1996). Clearly, research has to find ways and means to breed crops that consume less water, and to develop other water-conserving measures.

ESCAP (2008) has suggested that greater attention to policy is required concerning water conservation, water pricing, diversions from surplus to deficit areas, and establishing and restoring water management structures and institutions. These include methods of harvesting, harnessing and conservation, under very complex and trying circumstances.

Cow manure to fertilize and prepare the soil for rice cultivation in Bin Phouc Province in Vietnam.

Silvo-pastoral systems

Silvo-pastoral systems are systems that integrate tree crops with animal production. The analysis of economic benefits, based on a review of available information, give the following results with reference to the integration of cattle with oil palm.

- Increased yields of fruit bunches and income; the costs of production are reduced by about 47- 60 %, equivalent to 21 – 62 Malaysian ringgit /ha/yr.
- Increase in animal production and income, arising from meat off take.
- High Internal Rate of Return (IRR); the IRR of cattle under integration was 19% based on actual field data.

The expanding area under oil palm offers major opportunities to integrate ruminants and increase total productivity. Other potentially important production systems have been developed and have been described elsewhere e.g. Devendra (2010) and Devendra et al. (2001). They include:

- Forage production for multipurpose use e.g. *Sesbania rostrata; Leucaena leucocephala; Gliricidia sepium; Caliandra* spp. in the three strata forage system (Nitis, *et al*., 1991; Horne and Sturr, 1999)
- Non-conventional feed resources (Devendra, 1993; Devendra and Sevilla, 2002; Makkar and Ankers, 2014)

The results have been extensively reviewed and are replicable in all tropical countries.

Guiding principles for increasing agricultural productivity

- Agriculture must continue to spearhead and expand food production systems, help to reduce nutritional problems, food insecurity and malnutrition.
- Food should be abundant and reasonably priced.
- R&D on production systems, food security and climate change merit high priority.
- R&D initiatives in rural areas need coordinated community-based participation of farmers, researchers and extension personnel.
- The development of productivity-enhancing new technologies must take into account useful elements of traditional systems.
- Small farmers, including women, if empowered, could make a big difference through their productive and innovative capacity, efficiency, and numerical strength.
- Successful models should be developed for demonstration, replication and expansion.
- Extension agencies and workers should promote informal training, open and easy communication, discussion, innovation, study tours and networking to vitalise agriculture (Devendra, 2014c).

Ruminants for development

In the arid and semi-arid areas, the value of small ruminants especially goats and sheep (Devendra, 2005), together to a lesser extent with buffaloes (Devendra, 2009b) and cattle, increases with increasing harshness of the biophysical environment and decreasing quality of the available feed resources. These species have a multifunctional role in which their contribution to nutritional and food security and especially to survival is paramount. Hence ruminants should be given high priority in the development of rainfed areas. The development of crop-animal systems can significantly contribute to sustainable food production.

Animal-agriculture or crop-animal systems are complex and difficult to change. New proposed systems would have to be demonstrably superior (Mahadevan and Devendra 1986; Devendra, 1989). The present level of ruminant production is low, but if ruminants are given much higher priority in the development of rainfed areas, they may significantly improve the contribution of LFAs in sustainable food production.

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