

Intensification of Integrated Natural Resources Use and Agricultural Systems in the Developing World

C. Devendra^{1*}

¹Consulting Tropical Animal Production Systems Specialist, 130A Jalan Awan Jawa, 58200 Kuala Lumpur, Malaysia

The Need for More Food

Food production to provide adequate supplies for mankind represents the single most challenge of our time. Is central to the agricultural landscape? The burning debate is how to maximise efficient and effective use of the natural resources to ensure food security, social, economic and environmental sustainability. The issue is whether adequate supplies of food to feed the rapidly increasing humans can avoid massive food crises and civil disorder. Thomas Malthus view in 1798 that food production and population growth are closely linked adds meaning to the present circumstances, given that the first Millennium Development Goal to halve hunger and poverty by 2015 is on course to fail. A World Bank study has indicated that 100 million additional poor people will be pushed back into poverty; this will further increase food requirements, increase pressure on the use of the productions resources, and the capacity of small farm systems.

The widespread view is that food production will not be able to keep pace with population growth and human requirements; although some optimists like Koning and van Iffersum [1] believe that the world has enough to eat. In the 1960s the world population was three billion, has now grown to over six billion, and is projected to increase to nine billion in 2050. The problems associated with this demand and the disparity on adequacy of food supplies in the developed world are largely in the developing countries where there are both chronic food deficits, occasional surpluses and endemic inadequacies in the developing world. Sub-Saharan Africa, suffers critically from malnutrition, famines and starvation and diseases – most notably HIV/AIDS; the Near East region with food scarcities, and South Asia with regular chronic droughts and also famines.

The Awesome Dilemma

Several awesome facts highlight *inter alia* the grave concerns about food production, and seriously question the capacity of national agricultural research systems (NARS) and participating donors to meet the challenges in the light of the following :-

- Agriculture and its share to the gross domestic product (GDP) is declining in many countries, and in East Asia, the Pacific and South Asia, this has dropped from 3.0% in the 1980's to a mere 0.1 in 2000-2003 [2].
- Inadequate and low productivity from the production resources. This will exacerbate food and nutritional insecurity
- Arable land is seriously limiting for expanding agricultural production due to a combination of overuse, increased pressure for use by humans and animals, and more recently land acquisitions by foreign concerns, companies and individuals for the development of industrial systems
- The disparity in projected annual requirement *per capita* consumption of meat and milk up to 2050 are 44 kg and 78 kg and 94 kg and 216 kg respectively in the developing and developed countries respectively [3].

- Global climate changes are anticipated to affect biodiversity and animal performance. IFAD (2009) has reported that climate change is expected to put 49 million additional people at risk of hunger by 2020, and 132 million by 2050 [4].

- Climate change will also affect plant growth, yields, and the quantity and quality of crop residues produced, which in turn will reduce animal productivity [5].

Pressure on Agricultural Productivity Growth

The drivers of the dramatic trends are many and *inter alia* are as follows:-

- Declining agricultural growth
- Continuing poverty and vulnerability
- Rapid population growth, food deficits and crises, consumer preferences and changing food chains
- Vulnerability and survival of small farm systems
- Inadequate technology application, intensification of production systems and resources in holistic systems
- Globalisation and trade liberalisation
- Reduced availability of arable land
- Poor market access and opportunities for producers and products
- Increased environmental concerns and threats of trans boundary zoonoses, and
- Need for affirmative and collective action to address the emerging problems.

The Concept and Rationale of Integrated Systems

Integrated systems link the natural resources crops, animals, land and water to economic, social and ecological perspectives. The process is holistic, dynamic, interactive, and multidisciplinary and promotes efficiency in natural resource management (NRM). Integration enables synergistic interactions to maximise productivity. Examples are swamp buffaloes providing draught power for land preparation, soil conservation and haulage operation in rice growing areas, and

***Corresponding author:** Dr. C. Devendra, Consulting Tropical Animal Production Systems Specialist, 130A Jalan Awan Jawa, 58200 Kuala Lumpur, Malaysia, E-mail: cdev@pc.jaring.my

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the integration of goats and beef cattle with oil palm results in value addition and increased fresh fruit bunches (FFB). Both ecological and economic sustainability are addressed in a mutually reinforcing manner. Such integrated systems are especially well developed in East and South East Asia, West Africa and parts of Latin America. Integrated systems are characterised by the following features:-

- Low input use
- Diversification of agriculture
- Extensive use of indigenous knowledge and traditional systems
- A high proportion of the land is used for food crops, mostly for home consumption and also food security
- Diversification and integration promotes feed security
- Cash crops are grown to generate income
- A mix of animals is present, but seldom are more than two species of ruminants reared together, and
- Poor access to market outlets and poor marketing arrangements.

Strategic Opportunities for Increasing Productivity

Many strategic opportunities exist for technology application to increase productivity and agricultural growth by engaging more assertive programmes *inter alia* on the following:-

Targeting rainfed areas

The justification for targeting the rainfed areas (marginal/less favoured + arid lands + forests and woodlands) are related to the following:-

- Underutilisation and potentially valuable for agricultural development
- Available rainfed area accounts for about 82, 90 and 92% of the total land area in Asia, Latin America and the Caribbean, and Sub-Saharan Africa respectively, found mainly in the arid/semi-arid zones and also sub-humid and humid zones [6].
- Presence of a large population of very resource-poor farmers and the landless who live in poverty and hardship. ESCAP (2012) estimates that a 1% increase in agricultural productivity would lead to a 0.37 % drop in poverty in the Asia-Pacific region,
- The ownership of mainly goats and sheep, but also of cattle and camels and nomadism [7] enables a means to earn income and survive. The available ruminants will provide the entry point for the development, and in time the intensive, integrated and efficient use of the production resources.
- Demand for agricultural land for housing, industrialisation and urbanisation
- About 86% of the total population-the poorest of the poor live in poverty here, in addition to the presence of about 51-55% of the total population of cattle and small ruminants in Asia
- Increasing and very high animal densities
- Expansion of intensive crop production to ceiling levels, and increasing environmental concerns e.g. acidification and salinisation with rice cultivation, and human health risks due to expanding peri-urban poultry and pig production, and

- Natural resource degradation is evident, and major challenges exist for their more integrated and efficient use.

The value of the rainfed areas is totally dependent on rainfall. When the rains fail, the potential disaster is explosive with several implications. These include more droughts, climate instability, failure of crop production and reduced grazing lands and feed availability. Millions of households and people with their camels, goats, sheep and cattle, are forced into semi-nomadism, are marginalised further into extreme poverty, starvation and vulnerability, erosion of biodiversity; and inevitable damage to the environment.

Priority development of small farms

The general neglect and bypass by most national programmes and donor agencies of the development of small farms is a sad reflection of our times. The estimated total number of small farms 4700 million (below two hectares of land), of which 87% or 348 million farms and about two million resource-poor are found in Asia. Many of these farms are models of efficiency in natural resource management and low resource input systems, producing food for subsistence and occasionally for income. No hard data exists on the volume and extent of food produced on these small farms, but it is widely believed that this is of the order of 50%. To suggest therefore that small farms are not competitive, are inefficient and will disappear in time, is unacceptable and irrational. Development must therefore hasten to give very high priority to their development to increase agricultural productivity, food security and overcome poverty. Massive investments and appropriate policy is required for community-based programmes to address and enhance the plight of small farms, small farmers and the landless from the throes of the key descriptors of *deprivation, subsistence, illiteracy, survival and vulnerability*, whose lives are a non-ending syndrome of a *poverty – adaptation – fragile lives – little hope – low life expectancy* complex [8].

Intensification of productivity-enhancing technology application and impacts

Increasing productivity in successful projects depends to a very large extent on the application of technology options from research that serves development. The potentially important productivity-enhancing technology options below have already been reviewed [9] and is given below. However, for illustrative purposes the first on the list is described also emphasising also its potential replication in Sub-Saharan Africa and Latin America. There exist a number of proven and potentially important productivity-enhancing technologies, the use of which can significantly increase productivity in animals. These include *inter alia*:-

- (i) Three-strata forage system
- (ii) Food-feed inter-cropping
- (iii) Integration of ruminants with tree crops
- (iv) Effective utilisation of crop by-products and non-conventional feed resources
- (v) Strategic supplementation
- (vi) Rice-vegetable-ducks-fish integration
- (vii) Sloping agriculture land technology
- (viii) Effective use of local feed resources: large scale beef production using ammoniated rice straw and cottonseed cake.

Three-stratum forage system: The three strata forage system

(TSFS) is an integrated way of planting and harvesting forages so that a source of feed is available year round. The core area is the centre of the plot where maize, soya bean and cassava are grown. The grasses, legumes and trees used were:-

Strata 1

Grasses: Buffel (*Cenchrus ciliaris*) and Green Panic (*Panicum maximum*) **Legumes:** Stylo (*gracilis*), Centrosema (*Centrosema pubescens*) and Caribbean stylo (*Stylosanthes hamata*)

Strata 2

Shrubs: Gliricidia (*Gliricidia sepium*), Leucaena (*Leucaena leucocephala*)

Strata 3

Fodder trees: Ficus (*Ficus poacellie*), Hibiscus (*Hibiscus tilleacius*), Lannea (*Lannea corromandilica*). The major highlights of the systems from the nine and a half year study are as follows:-

- Increased forage production enabled higher stocking rates (3.2 animal units/ha) and total live weight gains of 375 kg/ha/year in the TSFS compared to 2.1 animal units and 122 kg/ha/year in the non-TSFS.
- Cattle in the TSFS gained 90% more live weight and reached market-weight 13% faster. Also farmers benefited by a 31% increase in farm income
- The introduction of forage legumes into the TSFS reduced soil erosion by 57% in TSFS compared to the non-TSFS, together with increased soil fertility
- The presence of 200 shrubs and 112 trees logged twice a year produced 1.5 tons/year of firewood, which met 64% of the farmers' annual firewood requirements
- The integration of creased the farmers' income
- Institutionalisation of the concept and the technology

Integrated tree crop-animal systems: the economic potential of the oil palm: Of the prevailing crop-animal systems, tree crop-animal systems are very underestimated, involving such plants as citrus, coconuts, oil palm and rubber. It is unfortunate that this system is being overlooked in the national development agenda. The oil palm is particularly important "golden crop and Asia had about 84% of the total world land area under oil palm of about 10.6 million ha and produced about 90% of the world palm oil output. The largest land areas under oil palm of 8.4 million ha are found in Malaysia and Indonesia, who together owned over 79% of the world planted area and produced about 87% of the total world output of palm oil, followed by much smaller areas being found in Thailand, Philippines, India and Papua New Guinea. Integration and the resulting interactions result in many benefits as follows:-

- (i) Beneficial effects of shade and available feeds on animals, especially exotic stock
- (ii) With large ruminants, draught animal power on land preparation and crop growth
- (iii) Dung and urine on soil fertility and crop growth
- (iv) Use of AIBP from trees *in situ*, and
- (v) Use of native vegetation, cost of weed control, crop management and growth.

Confirmation of above is reflected in the results from 21 case studies over the period (1984-2007) which showed distinct economic impacts [11]:-

- Integrating goats was advantageous
- Improved soil fertility was evident
- Distinct economic benefits are apparent e.g. crop yields and savings on weeding costs with concurrent increased profits, and
- Decreased carbon atmospheric emissions due to improved forage management.

The integration also enables stratification and production options. increased breeding of animal numbers, intensive utilisation of the available forage biomass and AIBP *in situ*, development of intensive zero grazing systems, improved NRM, interdisciplinary R, and D. in holistic systems, and increased market outputs and marketing.

Challenges for Sustainable Intensification and Increased Productivity

There is no doubt that well formulated and targeted R and D programmes, including the experience of the Green revolution, can result in significant outputs in productivity. This assumes that affirmative action is also used to resolve prevailing deterrent factors such as waning agriculture, constraints to decreasing agricultural productivity, the awesome dilemma of inadequacy of food supplies to meet human requirements – now and projected, inadequate application of appropriate technology and poor delivery systems to farmers. Four factors are central to ensure success of the strategy and are as follows:-

Defining a policy framework

A policy framework is an important prerequisite to focus priority development of the rain-fed areas. Agricultural research in this case is complex and long term, and will need government-led with institutional commitment, recognising that the rates of return to new technologies and sustainable agriculture are high. Agricultural growth is therefore an important driver of productivity growth. Two other aspects of policy which are important concerns promoting private sector investments by strengthening property rights, and encouraging relevant developing country R and D that are more sensitive to local food insecurity concerns and improved livelihoods.

Resolution of priority constraints using systems perspectives

A vigorous agenda for sustainable agricultural production in the future will require increased commitment to a few key elements: focus on target priority AEZs, community-based interdisciplinary R and D, and application of farming systems perspectives in whole-farm situations, The framework for R and D will address the priority issues within the evolving scenarios such as nutrient flows, overgrazing, year round feeding systems and zoonoses. Specific problems cannot be resolved by a single discipline alone, which has been a major weakness of many research programmes involved with NRM in the past.

Available agro-technologies, delivery systems, application and impacts

The determination of appropriate agro-technologies needs to recognise the key words of *problem definition and priority setting*. It is now widely acknowledged that systems perspectives are fundamental for productivity enhancement from integrated NRM. This is especially

the case with mixed farming systems with the diversity of crops and animals, traditional methods of farming, multifunctional contribution of animals, multiple crop-animal interactions, and numerous problems of farmers, As far as possible, R and D activities should be location- and country-specific rather than be dependent on imported technologies which have other objective and not entirely suitable. Also, imported technologies often have to be adapted to the, local environment to which there is no guarantee of success. In the past technology transfer was consistent with talking and persuasion, but in today's circumstances extension involves helping farmers to increase production, to marketing arrangements, funding and managerial arrangements [11].

Investing in agriculture

Investing in agriculture R and D is the key determinant of agricultural growth and improved productivity. This needs major public agricultural research (governments, universities and non-profit agencies), and the private sector as well. A large body of evidence clearly indicates that productivity improvements to investments in agricultural R and D, in which the estimated returns are high, and high enough to justify an even greater investment of public funds [12], Reversing declining agricultural growth is feasible, and calls for keeping food prices low, and increasing the level of R and D to the extent possible. The combined thrust of using problem-solving research results, efficient research-farmer-extension delivery systems for appropriate agro-technologies, backed by sustained investments can impact on demonstrable integrated NRM. Intensification is inevitable and will lead to increased agricultural productivity and growth which will improve the alleviation of poverty and vulnerability. The enduring hope in the long term is sustainable agriculture, improved livelihoods and self-reliance [6].

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