

Rethinking Agriculture: Agrobiodiversity for Sustainable Production Intensification¹

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There is now growing interest and movement in broadening the so called 'modern agriculture' paradigm to include practices that are biologically-driven and environmentally friendly. In fact, the industrial paradigm that has been promoted during much of the 20th century is running out of steam because the assumptions and practices upon which it is based no longer meet the overall needs of the society. To understand where we are in terms of agriculture development, where we have come from and where we need to go, some fundamental questions must be posed, namely: What is modern agriculture? What are some of its major consequences, and the underlying reasons for them? How well suited is modern agriculture for the future? Do we need to rethink some of our 'modern' attitudes and approaches to agriculture and to agrobiodiversity?

What is 'modern' agriculture?

[Box 1]

A DEFINITION OF AGROBIODIVERSITY

The variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries.

It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems.

Source: FAO, 1999

Modern agriculture is the agriculture that is practiced by the developed industrialised nations. This agriculture is the outcome of the application of science and technology to traditional farming based on the dominant 19th century approach of industrialisation-led growth for development. The characteristics that were central to the industrial revolution in the manufacturing industry were applied to farming in the first half of the 20th century and led to standardisation, mechanization, the adoption of labour-saving technologies and the use of chemical inputs to feed and protect the crops. In the second half of the 20th century, this industrialization process was increasingly shaped according to the scientific formulations based on the use of the genetic potential of fewer crops and their cultivars for high yields

together with heavy dependence on production inputs, increased energy and capital intensities backed up with market and trade driven globalization.

¹ The views expressed in this paper are the personal opinions of the authors.

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What are some of the major consequences of 'modern' agriculture?

The major consequences of intensified modern agriculture have been considered to be the ability to feed the world and avoid the Malthusian outcome. But this unprecedented success has come with a large environmental and human health cost, resulting from: the destruction of soil health, soil biological functions and soil porosity with excessive tillage, use of agrochemicals and decrease in biomass recycling; the loss of soil biota and carbon; increase in soil erosion and flood generation; water scarcity; pesticide contamination of soil, water and food; and severe decline in biodiversity and in farmland birds and wildlife. In fact, the core cause of many of the negative externalities arising from modern agriculture are linked to the destruction and reduction of the biodiversity in agricultural landscapes, referred collectively as agrobiodiversity (see Box 1 for definition), and the many agro-ecosystem and ecosystem functions and services which they perform (see Box 2). In this paradigm of tillage-based modern agriculture, the distorted market-driven competition that is unable to bear full costs and the profit objective to maximise return on capital and financial investment, rules supreme. As a consequence, any degradation of the natural resource base, biodiversity, the environment and human health associated with agriculture and food system features largely as unavoidable trade-offs or consequences that the society must bear and pay for. One major manifestation of this is the drastic reduction in crop, soil and farm agrobiodiversity, and in total biodiversity in rural landscapes.

[Box 2]

THE ROLE OF AGROBIODIVERSITY

Experience and research have shown that agrobiodiversity can:

- Increase productivity, food security, and economic returns
- Reduce the pressure of agriculture on fragile areas, forests and endangered species
- Make farming systems more stable, robust, and sustainable
- Contribute to sound pest and disease management
- Conserve soil and increase natural soil fertility and health
- Contribute to sustainable intensification
- Diversify products and income opportunities
- Reduce or spread risks to individuals and nations
- Help maximize effective use of resources and the environment
- Reduce dependency on external inputs
- Improve human nutrition and provide sources of medicines and vitamins, and
- Conserve ecosystem structure and stability of species diversity.

(Adapted from Thrupp, 1997)

An underlying reason for the above negative consequences is that the scientific formulations that underpin modern agriculture are based on mainly reductionist thinking and partial approaches to system analysis and scientific investigations, and to public policy formulation. Consequences of this include:

Public agricultural research system being largely unable to adequately handle experimental research on knowledge intensive agro-ecological concepts, approaches, technologies and practices such as Conservation Agriculture (CA), Integrated Pest Management (IPM), Integrated Crop Nutrient Management (ICNM), the System of Rice Intensification (SRI), or socio-cultural research on Farmer Field School type learning approaches, or on patterns and forms of social organizations, or on community-based institutions.

Narrow on-station research agendas unable to integrate agro-ecological and socio-cultural realities of the producers into scientific innovation processes.

Funding of agricultural research often directed towards quick results; less and less funding on research related to knowledge intensive concepts and technologies whose benefits improve over time, such as, CA, IPM or ICNM.

Public sector agricultural scientific research and career promotion system remain largely trapped within self-serving peer review processes for journal publication.

Private sector scientific research which is not always geared to produce technologies and knowledge in the public interest or in the interest of animal welfare or the environment or agro-biodiversity or wild life.

Much of the crop productivity research is 'genocentric' with less and less importance given to crop eco-physiology, analytical agronomy, biological or natural pest control, landscape agro-ecology and agrobiodiversity, soil biology, Conservation Agriculture, ecoagriculture, agro-ecosystem management, etc.

The biological and ecological processes studied and modelled by agricultural scientists assume that these biologically-driven phenomena and processes behave or can be simulated mainly as physical or mechanical processes.

Hence, for example, soil as a living biological system interacting with plant root system and with soil agrobiodiversity including beneficial organisms in mutual self-empowerment relationships rarely features in any agricultural research and models on crop or land productivity or sustainability; similarly crop diversification as an essential agrobiodiversity element of sustainable production system hardly features in crop productivity models.

Agricultural education and advisory services which are largely based on the above scientific formulations and concepts in support of the industrialised 'modern agriculture' as something which is suitable not only in the developed regions but globally.

How well suited is modern agriculture for the future?

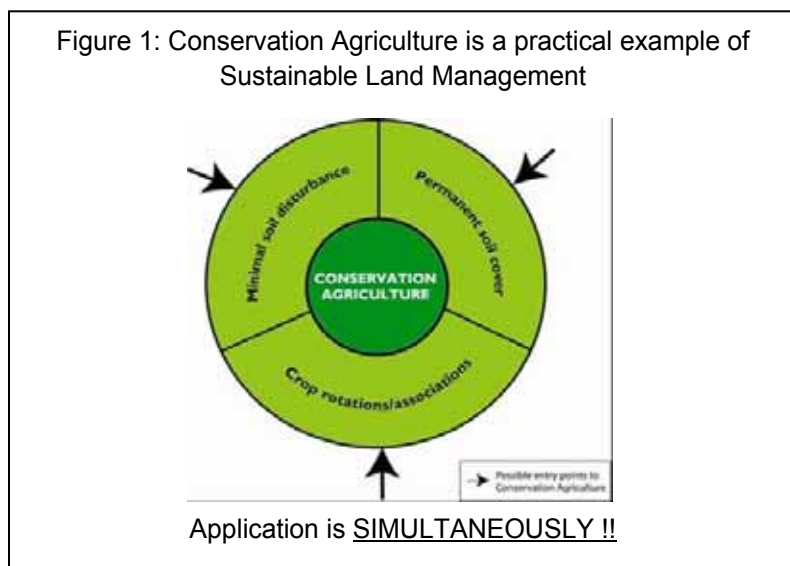
Given the 21st Century realities of diminishing returns to inputs, stagnating yields, rising food prices, high energy costs, serious environmental concerns, climate change, declining per capita water and land resources, and pervasive rural poverty, a "more of the same" strategy (including the scientific formulation system supporting 'modern agriculture') for future agricultural development makes less and less sense. Indeed, it can be argued that the current "Green Revolution" attitudes and approaches to modern agriculture do not constitute a set of suitable paradigms for future agricultural development in the developing regions, nor do they appear robust enough to maintain the viability and environmental integrity of agriculture in the developed regions.

Consequently, in the European Union, the focus of the Common Agricultural Policy (CAP) in recent years has shifted from production subsidies to single farm payment for environmental management services. However, the stewardship schemes that are promoted are not adequately linked to protecting and enhancing agrobiodiversity for sustainable production. For example, there is no systematic recognition of the positive and essential role played by crop and soil agrobiodiversity in sustainable production intensification. Thus, there is no incentive offered to promote production practices such as CA, IPM or ICNM, all of which are well known for their ability to enhance and utilise agrobiodiversity for improved crop productivity.

Do we need to rethink some of our attitudes and approaches to ‘modern’ agriculture and to the use and management of agrobiodiversity?

Given what we now know about the negative consequences and unsustainable nature of modern agriculture, the answer to the question is a resounding ‘yes’. The reason for this can be illustrated by the sustainable land management practice called Conservation Agriculture (CA). This production system is as an example of what agroecologically sensitive technological changes are emerging that are pro-agrobiodiversity and may become prevalent in the future? According to the Food and Agriculture Organization of the United Nations, which has done a great deal to promote it, CA is:

“a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes. CA is characterized by three interlocked principles of continuous minimum or zero mechanical soil disturbance (i.e., direct planting of seeds); permanent organic soil cover, especially by crop residues and cover crops; and diversified crop rotation in the case of annual crops or plant associations in the case of perennial crops.” (see Figure 1, FAO website: www.fao.org/ag/ca/)



Today, there are some 100 million hectares of agriculture land under CA practice, particularly in North and South America and Australia, and now increasingly in Asia. Europe has less than 0.5 million hectares under CA, reflecting the largely static or archaic European land management framework that is supposed to

promote responsible land use stewardship by farmers. Instead, land use and agrobiodiversity management in Europe remains in a sub-optimal state. However, in Brazil for example, where there is some 25 million hectares of land under CA systems including cover crops in the rotation, maize yields over the past 20 years have doubled to 8 t/ha while fertilizer input has decreased by 30%; similarly for soybean which increased its yield from 2.2 t/ha to 3.6 t/ha with simultaneous decrease of 50% in fertilizer application.

In terms of its effect on soils, CA adds up to 1 mm soil per year; organic matter and soil biota increases at about 0.1-0.2% per year until reaching a saturation; a diversity of rooting systems from a diversified crop rotation and association provide for more efficient use of soil nutrients and biologically fixed nitrogen; soil structure through the workings of a diverse set of microorganisms is more stable and porous with lower bulk density and higher Cation Exchange Capacity, and soil erosion and degradation is stopped/reversed (see Figure 2). The effect of CA on water include: fuller recharge of aquifer (permanent soil pore structure due to soil biodiversity, plant roots and root exudates maintaining the soil micro and macro pores); improved water quality (less leaching and erosion due to surface protection with plant organic matter cover from a diverse source of crops); more soil available water to crops due to higher soil organic matter (SOM) (1% SOM = 150 m³/ha); reduced surface water losses (decrease in soil evaporation); and better water efficiency (crop water requirements decrease by some 30%) and increased water productivity (more crop per drop). Additionally, there is a significant reduction in flood risk under CA. This is because water infiltration rates under CA are more than 120 mm/hr compared to 20 or 30 mm/hr for soils under tillage-based farming. Similarly, there are beneficial impacts of the diversified CA cropping system on weeds, pathogens and insects pests, reducing overall use of pesticides; and CA-based agrobiodiversity above and below the ground surface contributes to climate change adaptation and resilience of the production system, and to climate change mitigation due to greater carbon sequestration and lower greenhouse gas emission.

Figure2: Soil comparison in a farmer's trial – Clods of topsoil from adjacent plots, Parana, Brazil (photo credit: Francis Shaxson)



PRO-BIOTIC ▲

Topsoil after 5 years with retention of crop residues and no-till seeding.

ANTI-BIOTIC ▲

Topsoil after regularly-repeated disk-tillage, without retention of residues.

The applicability of CA principles are universal, with local solutions; CA applies to all sizes and types of farmer; with appropriate equipment and farm power, large-scale CA-based agronomic practices are easily adapted to small farms; CA is possible on all agricultural soil types. Advantages with CA for the farm can include: some 50% labour saving; up to 70% fuel saving; about 50% saving in machine capital (tractors); and 40% smaller tractors with 3-fold increase in their lifespan. Other benefits have included: higher and stable yields, and less climate risk and higher profit. For rural communities, CA means reduced pollution due to less pesticide use, lower cost for water treatment, more stable river flows, and lower cost for road/waterway maintenance.

CA represents a kind of agrobiodiversity-driven agro-ecological approach to simultaneously managing sustainable agricultural intensification and ecosystem services. Instead of always changing varieties in monocultures and investing in more agrochemical and energy inputs, CA changes the total sum of agrobiodiversity in the production system and the way they, including the plants, soil, water, nutrients, soil biota, and soil organic matter in space and time, are managed with the result that the land's productive capacity (and indeed the health and potential of the whole agro-ecosystem) is enhanced, rendering a variety of beneficial services, including pollination and the protection of crops, livestock, wildlife and the environment. Other beneficial practices such as biological control of pests, integrated pest management, and integrated crop nutrient management, also offer cost reductions, enhanced ecosystem services and landscape biodiversity, and higher productivities and income.

CA is particularly beneficial to below ground soil biota and agrobiodiversity which is believed to improve four main aggregate ecosystem functions (Swift *et al.*, 2008): (i) decomposition and humification of organic matter and root exudates brought about by the enzymatic activity of bacteria and fungi, and facilitated by soil animals such as mites, millipedes, earthworms and termites; (ii) nutrient cycling which is closely associated with organic decomposition, with transformations mediated through microorganisms; (iii) soil structure maintenance through the activities of plant roots, earthworms, termites, ants and some other soil macrofauna in the soil that form channels, pores, aggregates and mounds, and moving particles from one horizon to another; and (iv) disease and pest control through for example the regulations of activities of pathogens by the microbiovore and micropredator portions of the soil biota that feed on microbial and animal pests respectively.

Concluding remarks

There is little doubt that all stakeholders -- producers, scientists, extensionists, policy makers, investors etc. -- need to seriously rethink some of the scientific and institutional attitudes and approaches to modern agriculture. It is timely to seriously review the human and environmental consequences of 'modern' agriculture and the research, education and institutional systems (including the private corporate sector) that support it. But are we really ready to help the developing world avoid the negative consequences of 'modern agriculture'? If we think we are, then what crop production and land management paradigm should we promote? What kind of agricultural research, education and extension systems will go with it? What paradigm will we adopt to

generate relevant knowledge intensive technologies and to integrate them into farmer practice to conserve the resource base, raise productivity, output and income, strengthen livelihoods and enhance ecosystem services? It would appear that there is plenty of 'rethinking' that needs to be done about the future of agriculture. Whichever way forward the rethinking goes, it appears to us that the central role of agrobiodiversity in sustainable production intensification is now beyond doubt, and worthy of it receiving greater attention in research, development and education.

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