Mobilizing greater crop and land potentials: Replacing the faltering engine

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The Size of the Supply Side

Latest estimates suggest that the world needs to produce some 60% more food to meet the needs of the expected global population of 9.2 billion at 2050. Recent FAO forecast indicates that this can be done if we can maintain an annual increase in food production globally at an average rate of 0.9%, with a variation in regional rates from 0.3% in Europe to 1.6% in Africa. In terms of the actual output of food, this corresponds to an increase in production of cereals from 2.52 billion tonnes in 2014 to 3.28 billion tonnes in 2050 from an area of 736 million hectares. This equates to an average yield of 4.33 t/ha to meet food, feed and biofuel needs as well as losses of some 40%. If wastage was halved, the yield required would be 3.46 t/ha, and the total output required would drop to 2.64 billion tonnes, not much more than what world agriculture is producing now. Reducing wastage is not going to be a simple matter because the issues involved are to do with the way we relate to food as we become more affluent and urbanized and the way the modern food system operates to supply our food needs. But we predict that there will be increasing pressure in the future from the consumers and governments to minimize wastage of food as prices rise.

We have used cereal output, net land area and yield to set the quantities involved on the supply side because two-thirds of our calorie needs are met by cereals. Also, the proportion of net land area under cereals to non-cereal crops is about 50:50. Thus the total agricultural land area required to meet global agricultural needs from annual cropping at 2050 would be some 1.53 billion hectares. There is additional need for land for permanent crops of various kinds which would suggest a total net land area needed for annual and perennial crops of around 2 billion hectares. Currently the total agricultural cropped area is 1.6 billion hectares. According to the GAEZ assessments, actual and potential suitable agricultural land area is 4.5 billion hectares. So the current net cropped land area corresponds to 36% of available suitable land area. In addition to suitable agricultural land, there is 2.7 billion hectares of marginal lands. This we believe includes some 0.5 billion hectares of land area that was once suitable agricultural land but has been abandoned over the years due to land degradation and erosion.

For the expected plateau population of 10 billion around 2100 and beyond, the total cereal required could be some 5 billion tones if everyone needed some 500 kg per capita of cereals, which is the current level needed in Europe to meet food, feed and biofuel needs and the amount that is wasted. This equates to a yield of some 6.55 t/ha assuming no more area expansion in net area beyond 2050 (i.e. 763 million hectares) and no decrease in wastage, or 5.24 t/ha assuming 50% decrease in wastage. Alternately, if we assumed an expansion of net land area for cereal cropping to 1 billion, then the corresponding yields would be 5.0 t/ha assuming current levels of food wastage, or 4.0 t/ha assuming a 50% decrease in food wastage. Whichever way the future unfolds, it would seem that the total net area required to meet global food and agricultural needs would be between 2 and 2.5 billion hectares.

Based on the assessments of land and water resources available, FAO and their collaborators continue to conclude that it should be possible to meet 2050 food and feed demand within realistic rates for land and water use expansion and yield development.

The 'Hidden' Reality of the Conventional Tillage-based Production Systems

While the supply side appears agronomically doable in terms of required yields, and that there appears to be enough available land and water resources to support the required output. But the reality on the ground on farms tells a different story.

The FAO future projections are based on the GAEZ assessments all of which assume the continued use of the tillage-based agricultural production systems. The assessments do not explicitly take into account the resulting degradation and loss of crop and land productivity that has been occurring over the past years and will continue in the future. The marginal suitability category of land in the GAEZ assessment includes much of the degraded and abandoned agricultural land whose original status is not assessed or unknown. Additionally, it is assumed that yield gaps can continue to be filled based on intensive tillage and increased application of production inputs. I other words, the paradigm assumed to meet future demand is 'business as usual'.

Conventional tillage-based production systems (sometime referred to as the Green Revolution approach) have generally become unsustainable for the future as they have been causing land and ecosystem degradation, including loss of agricultural land, and loss of productivity and ecosystem and societal services. This Green Revolution approach does not seem to be going anywhere now even in the nations where it is claimed to have made an impact. For example, it is often stated that countries in Asia were the first to benefit from the Green Revolution, but the question is why did it not continue to spread? In fact the conventional 'modern' approach to crop production intensification based on expensive intensive tillage, seeds and agrochemicals is often not affordable by resource poor smallholder farmers, nor does it lend itself to socio-culturally inclusive development given that all the individual interventions must fit into some form of a 'business model'. Also, where Green Revolution approach is forced upon a country or a community, for example in Zambia or Malawi, the expected increases in yields do not occur, sometimes quite the opposite, leading to indebtedness, corruption, marginalization and suicides. This has led some donors such as Bill and Melinda Gates Foundation and Rockefeller Foundation to set up special research-led development initiatives such as AGRA – Alliance for Green Revolution in Africa but these do not seem to be creating much impact.

The point we are making here is that the so called Green Revolution approach has led, particularly since WWII, to a paradigm for production intensification that is based on intensive tillage and the notion that more output can only come from applying more purchased inputs. This mind-set also includes the indoctrination and creation of a behavioural culture in agri-*culture* that farmers and their service providers and governments do no need to worry about the negative externalities or understanding what should be the ecological basis of sustainable production intensification that can enhance productivity along with enhancing ecosystem services while at the same time perform at the highest possible efficiency and resilience, including climate change adaptability and mitigation. Nor is there any concern being expressed about agricultural land area continuing to be severely degraded and abandoned in the North and the South due to the negative impact of conventional tillage-based production paradigm.

Further, as tillage intensity and top soil pulverization has increased with production intensification, in conventional production systems, this has been accompanied by greater exposure of bare soil to changes in weather and the crops to climatic stresses, and decrease in the diversity of crops in cropping system, and increase in mono-cropping. These practices in the tillage-based conventional production systems have all contributed, at all levels of development, to soil degradation and loss of agricultural land, decrease in attainable yields and input factor productivity, and excessive use of seeds, water, agrochemicals and energy, increase cost of production and poor resilience.

The consequence of tillage-based production systems can thus be summarized as follows:

- Loss of soil organic matter, porosity, aggregate stability, aeration, biota (=decline in soil health -> collapse of soil structure -> compaction and surface sealing -> decrease in infiltration)
- Water loss as runoff and soil loss as sediment
- Loss of time, seeds, fertilizer, pesticide (erosion, leaching)
- Less capacity to capture and slow release water and nutrients
- Less efficiency of mineral fertilizer: "*The crops have become 'addicted' to fertilizers*"
- Loss of biodiversity in the ecosystem, below and above soil surface, mono-cropping
- More pest problems (breakdown of food-webs for micro-organisms and natural pest control)
- Falling input use efficiency and factor productivities, declining yields
- Reduced resilience, reduced sustainability
- Poor adaptability to climate change & mitigation
- Higher production costs, lower farm productivity and profit
- Dysfunctional ecosystems, degraded ecosystem and societal services including water, nutrient and carbon cycles, suboptimal water, nutrient and carbon provisioning and regulatory water services, and loss of landscape biodiversity
- Unacceptable food, agricultural and environmental costs passed on to the public.

This is why we say that if we are to: (i) mobilize greater crop and land potentials sustainably to meet future food, agriculture and environmental demands; (ii) maintain highest levels of productivity, efficiency and resilience ('more from less'); and (iii) rehabilitate degraded and abandoned agricultural land and ecosystem services, we need to replace the faltering production engine, the conventional tillage-based production paradigm, and transform the food and agriculture systems that is built upon it.

Switching Over to Hope for the Future with Conservation Agriculture

Soil's productive capacity is derived from its many components (physical, biological, chemical, hydrological, climate) all of which interact dynamically in space and time within cropping systems. A productive soil is a living biological system and its health and productivity depends on managing it as a complex biological system, not as a geological entity.

A regularly tilled soil, whether with a hand hoe or with a plough, eventually collapses and instead of having 50 to 60% air space in a healthy undisturbed soil, tilled soils have some 10 to 20% air space and no significant network of biopores. Of the 50 to 60% air space in a healthy soil, some 50% is filled with water, thus serving as a major buffer again climatic variability. On the other hand, a regularly tilled soil would hold much less water due to its much lower air space.

Scientific studies and empirical evidence have shown that the biology of the soil and all the biological processes along with the other chemical, hydrological and physical processes depends on soil organic matter. So the real secret of maintaining a healthy soil is to manage the carbon cycle properly, so that the soil organic matter content is always as high as possible above 2%, the soil is not disturbed mechanically and that soil surface is protected with a permanent layer of organic mulch cover. In addition to maintain and support the natural enemies of pests, a food web must be allowed to establish itself in the field.

To harness the conditions sufficient for achieving sustainable production intensification, agriculture must go back to its roots and rediscovering the importance of healthy soils, landscapes and ecosystems while conserving resources, enhancing natural capital and the flow of ecosystem and societal services at all levels.

The no-till production paradigm, known as Conservation Agriculture (CA), is totally compatible with the above goal as defined by its following three interlinked principles:

- **Minimizing soil disturbance by mechanical tillage** and whenever possible, seeding or planting directly into untilled soil, in order to maintain soil organic matter, soil structure and overall soil health.
- **Enhancing and maintaining organic mulch cover on the soil surface**, using crops, crop residues and cover crops. This protects the soil surface, conserves water and nutrients, promotes soil biological activity and contributes to integrated weed and pest management.

- **Diversification of species** – both annuals and perennials - in associations, sequences and rotations that can include trees, shrubs, pastures and crops, all contributing to enhanced crop nutrition and improved system resilience.

Implementing the above three principles using locally appropriate practices, along with other good practices of crop, soil, nutrient, water, pest, energy management, the above principles appear to offer entirely-appropriate solution, potentially able to slow or reverse productivity losses and environmental damages. They also offer a range of other benefits, which generally increase over time as new and healthier soil productivity equilibrium is established, including:

- Increase yields, farm production and profit, depending on the level of initial degradation and yield level.
- Up to 50% less fertilizer required if already applying high rates, and greater nutrient productivity with increased soil organic matter level.
- Some 20-50% less pesticides and herbicides required if already applying high rates, and greater output per unit of pesticide or herbicide. In the case where pesticides and herbicides are not used or available, integrated weed and pest management can achieve adequate pest and weed control.
- Up to 70% less machinery, energy and labour costs. In manual production systems there can be a 50% reduction in labour requirement as there is much less or no labour required for seed bed preparation and for weeding.
- Increase water infiltration, water retention and up to 40% reduced water requirement and increased water productivity.
- Greater adaptability to climate change in terms of more stable yields, and lower impact of climate variability from drought, floods, heat and cold.
- Increased contribution to climate change mitigation from increase soil carbon sequestration, reduced greenhouse gas emissions, and decrease in the use of fossil fuel. Additionally, lower carbon and environmental foot print due to reduced use of manufactured inputs such as agrochemicals and machinery.
- Lower environmental cost to the society due to reduced levels of water pollution, and damage to infrastructure such as roads, bridges and river banks due to reduced erosion and floods.
- Rehabilitation of degraded lands and eco-services from all agricultural land under use as well as from abandoned agricultural land in which the eroded topsoil and the soil profile need to be rebuild.
- Greater opportunity for establishing large scale, community-based, cross sectoral ecosystem service programmes such as the watershed services programme in the Parana Basin in Brazil, and the carbon offset trading scheme in Alberta, Canada.

The above benefits have now been documented on large and small farms throughout the world, and increasingly greater attention is being paid to support the adoption and scaling of Conservation Agriculture by governments, international research and development organizations, national research and development bodies, NGOs and donors as it is seen as a viable option for sustainable production intensification and an effective way to commercializing agriculture.

In 2013, the global spread of CA is 157 million hectares, and since 2008/09 when there were 107 million hectares. This corresponds to annual rates of expansion of 10 million hectares per annum. Some 50% of the area is in the developing regions and 50% in the industrialized world.

Conclusions

We draw the following conclusions:

- Meeting 2050 food demand is agronomically doable, and enough land and water resources are available.
- But business as usual, and continuing to rely on conventional tillage-based farming system for further intensification of agricultural production, is not an option to meet future needs sustainably.
- Production systems based on ecosystem approach must contribute to meeting future needs
- CA systems (including for rice-based systems) do this most effectively.
- CA is potentially applicable in most land-based agro-ecosystems, and all cropping systems in rainfed and irrigated conditons.
- CA is increasingly seen as a real alternative and constraints to adoption are being addressed. Now increasing at the annual rate of 10 M ha, and covers more than 155 M ha.
- Land, water and climate constraints affect regions differently. All regions, but especially resource-poor regions, would benefit from CA.
- For developed regions, with CA can improve profit, sustainability and efficiency at high yields with less degradation.
- For developing regions, CA offers greater output and profit to small and large farmers with less resources and land degradation.
- CA is capable of rehabilitating degraded lands and ES world-wide.
- Policy and institutional (including education) support, farmer organizations and champions are needed to mainstream the adoption of CA.