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AGRICULTURE AND RESOURCE MANAGEMENT: FUTURE NEEDS IN EUROPE AND DEVELOPING COUNTRIES[1]

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Introduction

Land that is suitable for agricultural production is a finite and vulnerable resource. Population growth and expanding demand for agricultural products constantly increase the pressure on land and water resources. Historically, increases in crop yield potential, intensification of cropping, and expansion in the area of cultivated land have all contributed to the expansion of world food production. Higher yields of crops, particularly the major cereal crops, derived from the development of high-yielding cultivars and greater use of agrochemicals and irrigation. Expansion of the area of cropped land has also contributed significantly to output; however, due to soil degradation and loss of agricultural land the net gain of productive land has been almost zero during the last four decades. Until the mid – 20th century the amount of arable land kept approximately pace with population growth. Large areas of land are annually removed from production as a result of degradation processes such as water and wind erosion, nutrient depletion, salinization, acidification and weed infestation.. This degradation is irreversible in some cases, or reversible only at great expense.

Over one half of the world's potential arable land is currently in production, but further expansion may be limited. Firstly, reserves are not evenly distributed and do not match the demands for land. Most of the reserves are in South America and sub-Saharan Africa; reserves are much smaller in North Africa and Asia, where many countries have little potential for expansion. Secondly, the production potential of much of unused arable land is marginal; most good quality agricultural lands are already in production. Thirdly, as much as half of the reserves are under forest or in protected areas not available for agricultural use.

Since land is a finite and fragile resource, its sustainable management depends on the husbandry of its different components, of which soil fertility and water availability are key factors for agricultural production. In Africa, due to poverty and the need to produce more food, the change in land use and farming practices results in soil organic matter depletion, nutrient mining and soil degradation (van Keulen & Breman, 1990; de Jager et al., 1998). In irrigated farming systems, the use of water and fertilizers, especially nitrogen, increased dramatically; a major point of concern for these systems is the agronomic efficiency of the use of water and nutrients. At the moment these agronomic efficiencies are often very low. The average recovery of fertilizer N in irrigated rice is only 30-40% and has not improved much over the past 30 years (Kirk, IRRI; pers. com.).

Global food security, population and resources

The world's population is increasing by about 1 billion people every 12 years. In 2020, the population is projected to be about 8 billion (United Nations Population Division, 1996). Increased resources are required for meeting the demands of this growing population, especially in the developing countries. Further increases are needed if the standard of living is to improve. In less developed regions, if resource use increases linearly with population, per capita use of resources will remain constant, and there will be little change in the quality of life. More energy and food needs to be produced solely to supply more people. Only if resource use increases at a faster than population, will there be a substantial increases in the quality of life.

Food security is a first priority for poor people. A growing population requires additional food, and over 90 % of food production requires directly or indirectly arable land. The drop in crop land relative to population is very evident. Up until the mid – 20th century there was in the order of 0,45 ha per person; in 1997 it had been reduced by almost a factor 2 resulting in 0,25 ha per person. Per capita grain production has a different pattern. There was generally an increasing production up to 1980,and a somewhat stable amount since then. These two patterns – more food per person from less land per person between 1950 and 1980, and constant food from less land between 1980 and the present – can be attributed to increasing amounts of fertilizer (Galloway,1998). However, the leveling off per capita grain production means that increases in grain production are only keeping pace with population growth. This fact and the increase in meat production may mean a decrease in food supply on average, to the world's population.

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At our present stage of knowledge, the main question is not if we can feed 8 billion people in 2020, but can we do it sustainably, equitably and on time in the face of the probable changes in climate. The assessment of the impact of these changes on agriculture relies heavily on both crop and climatic modeling. The output of the models is greatly influenced by the extent of our understanding of our crops, soils and climate. Researchers of Wageningen University and Research Center (Penning de Vries et al., 1995) have added to previously analyses of world food production based on alternative production and consumption technologies. There are major differences in the potential supply and demand for food in different parts of the world. Analyses were therefore carried out for 15 regions of the world. The question was if the world is approaching the biophysical limits of food production. In this research nine food demand scenarios were analyzed, ranging from minimum population growth combined with a vegetarian diet to maximum population growth combined with an affluent diet containing an ample amount of animal products. At a global level four times more food can be produced than required using environment-oriented agriculture and nine times more using ecotechnology-oriented agriculture. In all cases, three times more land is required for environment-oriented agricultural production systems than for ecotechnology-oriented systems. Consequently, the choice of the production technique has a major effect on global and regional land use. Depending on the diet selected Europe can grow an adequate food supply on 30-50 percent of its suitable land. North America on 20 percent of its land and south America on even smaller fractions. With an environment-oriented agriculture, all regions can produce the food required even for an effluent diet, except for East, South and Southeast Asia. The three regions with the least leeway will carry almost half of the global population. West Asia and North Africa come close to the lower limit, because there fresh-water resources are limited. This region does already depend very heavily on food imports; the problems of food supply will grow fast because of the rapid growing population and the scarcity of fresh water.

Resource use efficiency and modeling

The impact of agriculture on natural resources has become a major global concern. A systems perspective has been found especially useful for studying the interactions between agricultural production and natural resources. System methods have a number of advantages over traditional approaches focusing on commodities:

- the approach considers a system in its totality. A farming system not only considers commodities, livestock and the household, but also interactions among these components.
- interactions among various system levels and the inputs and outputs of the system are taken into account.
- system methods are very suitable for agricultural research in environments that are characterized by spatial and temporal variability.

System approaches were introduced in the seventies and are used increasingly in research on food production studies, natural resource management, land use options and rural development, since (Rabbinge, 1996).

Agriculture has to meet at a global level a rising demand for marketable outputs, while satisfying even tighter constraints with respect to safety of products and impact of production techniques on man, environment, nature and landscape. The attainment of these goals requires a comprehensive and integrated research approach. It is the synthesis of knowledge from various disciplines into a coherent framework, subsequently used to develop, implement and evaluate location specific farming and management options (Porceddu & Rabbinge, 1997).

Actually, in the last decades we have witnessed the integration of process specific knowledge into very precise, widely accepted relationships between processes in the system and driving factors from outside the system. System analyses and simulation are very functional in that integration. Simulation models are simplifications of the real system functioning. The fact that models require well defined hypothesis on systems behavior and an adequate interpretation of the results needs to be stressed.

Recently mathematical modeling has begun to integrate our understanding of the soil-plant N cycle and the soil, plant, environmental factors which govern it. However the complexity of the cycle and the large number of interactive factors which control it means that, even for temperate agricultural soils, the models do not closely approach reality. Environmental concerns are focused on nitrogen losses from soils which may pollute the environment. Leaching is the major route by which nitrate enters the ground and surface waters, while denitrification and nitrification are significant sources of N_2O, an important greenhouse gas.

Improved efficiency of N-use at a field and farm scale, both increasing crop yield and quality and reducing losses , is dependent upon dynamic optimization to match supply of N and the N requirements of the crop at a field scale. This optimization requires measurement and prediction of soil N supply, crop uptake and their variability (Stockdale E.A. et al., 1997).

Models of crop growth, the soil N cycle and plant – soil models have been developed. However, these are little used in current fertilizer and farm management recommendations. Farmers cannot wait for our understanding of plant-soil dynamics to be perfect, but need researchers to put their current knowledge to use.

Smart farming technologies aiming at both productivity and efficient gains are promising. New diagnostic approaches for field crops such as the use of near red reflectance and chlorophyll meters show promise but research is needed to clearly establish the relationships between the indicators and plant N uptake. Diagnostics could be used to increase the specific nature of recommendations or to adjust model recommendations during the growing season. This would enable a greater use of dynamic optimization strategies in the field.

By applying a simple rice-nitrogen model, MANAGE-N, it was possible to improve the timing of nitrogen dressing (ten Berge & Riethoven, 1997). For each user-defined fertilizer N-dose, the model identifies the timing and amount of split – applications, associated with maximum grain yield and maximum agronomic N-efficiency (kg grain per kg N applied). Improved timing of nitrogen resulted in yield increases of 4 – 10 % at a fixed total dose. Changing the N dose to the predicted economic optimum rate resulted in additional increases up to 13%. These positive results with rice are in line with the results of nitrogen split-dressing experiments in winter wheat in Europe some 25 to 30 years ago (Dilz et al., 1982). The demand of the fast growing grains in wheat is much higher than the uptake of nitrogen by the crop; relocation of nitrogen from the vegetative to the generative parts becomes very important for high-yielding crops. Better protection and agronomic support, combined with more prolonged photosynthetic activity of leaves should allow a better use of solar radiation at the end of the growing season (Spiertz & de Vos, 1983).

Contrary to the wide-spread view that high-input agrosystems are homogeneous, many researchers have found large spatial and temporal differences in nutrient levels and fertilizers efficiencies, even on similar soil types. Differences between fields are in part due to historical differences in management. But the major cause of low and varying fertilizer use efficiency, particular for N, is that the supply of nutrients from soil reserves and fertilizers is not well synchronized with the demands of the crops, and managing fertilizers to improve this synchrony is complicated.

Agronomic intensification and innovation will no doubt continue, with more of nutrients and other inputs applied to crops in an appropriate form, a better timing and a more targeted site-specific application, with more effect and less loss and adverse side effects (Evans, 1999). Synlocation and synchronization of fertilizers have been developed as a scientific concept. Precision farming methods will implement these concepts in practice, but at some costs. Crop protection will become more comprehensive and integrated. This development in crop production was characterized by Rabbinge (pers. com.) as *«ecological modernization»* .

Opportunities and constraints for fertilizer use

For centuries crop available N was determined primarily by the status of soil reserves, biological fixation and the cycling of N within farm or village boundaries. Off-farm sources of N were historically limited to various organic materials including guano and human organic wastes. The development of industrial N fixation in the late 19th century became the basis for dramatic changes in the spatial dimension of the nitrogen pathways in agriculture. Nitrogen fertilizer use developed in many industrialized countries slowly because of shortage in fixation capacity, storage and transport facilities, but mainly to a lack of agricultural technology. Under these circumstances N-fertilizer use was often not beneficially in terms of costs and returns.

During the period of early fertilizer use but intensified crop production, the nitrogen use was inadequate to offset the nutrient exploitation that was occurring. The break-through in nitrogen fertilizer use came with the introduction of newly emerging agricultural technologies such as:

- hybrid corn and semi-dwarf cultivars of wheat and rice, the so-called high yielding varieties;
- increased irrigation capacity;
- chemical control of weeds, pests and diseases;
- improved land reclamation, especially drainage of heavy textured soils;
- improved application methods.

These developments are strongly related with relative low fossil energy prices. The availability of N-fertilizer from industrial fixation made new spatial dimensions of the N-pathways in agriculture and environment possible. Access to fertilizer nitrogen has extended the boundaries of agro-ecosystem analysis beyond the familiar landscape unit of an individual farm and the control of the agro-ecosystem beyond the decision making of the farmer. Spatial separation of the traditional N- cycle compartments of crops, animals and soils in contemporary agriculture and the identity and emerging roles of those who control the pathways of N-movement are unresolved issues confronting N-cycle formulations and agro-ecosystem analysis. The new challenge is to co-ordinate the management decisions by the many farmers and the others involved in the spatially extended pathways.

Significant changes in managing the impacts of N-losses from farms to the environment exist in the specialized agro-production regions. The problems are most significant in regions with an intensive animal production. The excess of nitrogen compounds in manure has become an issue of major concern in many European countries and will become also an increasing problem in other countries, like India and China, with a high stocking rate of animals. Animals use nutrients in feed only partially; the nitrogen use efficiency of dairy cows is less than 30% depending on the composition of the feed. A higher protein content results in higher excretion of urea. In Europe and especially in the Netherlands, there exists a set of regulations set by the government to protect the environmental compartments - soil, water and air – against nutrient losses from agro-production.

The Dutch government imposed a policy that will lead to a balanced application of manure and fertilizer. This is to be brought about by the introduction of the Minerals Accounting System (MINAS). Under this system farmers are to keep records of the exact amount of minerals they use, the quantities that leave the farm and the quantities lost to the environment. If the surpluses exceed a given standard the farmer is to pay a heavy fine. The new system enables farmers to get a realistic insight into the actual amounts of nitrogen and phosphate entering and leaving the farm. A certain amount is inevitably released into the environment, for which levy free standards have been established. Levy free surpluses for phosphate and nitrogen on arable land amount to 40 and 175 kg per ha, per year at the moment; these standards will be reduced in the next decade to 20 and 100 kg of phosphate and nitrogen, respectively. With a balanced application of nutrient inputs the EU Nitrate Directive's objectives can be met and nitrate levels in groundwater will not exceed the standard of 50 mg nitrate per liter.

A biological feature that was of considerable value in sustaining farms in the past has become an environmental liability in the newly emerged, spatially extended agro-ecosystems. However, a more environmentally sensitive nutrient management on the field and farm level can reduce nitrogen losses to a level that meets the standards of a clean environment.

An improved dairy farming system was implemented in a fragile environmental region at a Dutch experimental farm, called «De Marke» (Aarts, et al., 1992). A whole farm strategy to improve the utilization of N in all components, resulting in less external inputs, has been developed. Results of this proto-type system show that farm inputs of N with feed and fertilizers can be reduced by 55%, compared to current farming systems, without reducing milk production below ca 12,000 kg per ha, nearly the Dutch average. N surplus was reduced by more than 60% and strict environmental goals with regard to quality of water (nitrate leaching) and air (ammonia volatilization) were met. These results of the experimental farm will be tested with 12 commercial farms, representing the full range of conditions for dairy farming in the Netherlands.

Concluding remarks

Given the growing population and the limited area of cultivated land there is an urgent need for further increasing the yields of crops combined with a sustainable use of non-renewable resources. Evans (1999) posed that it is not a small challenge to scientists and farmers in view of:

- environmentalists and other pressures against both further intensification of agriculture and the extension of irrigated areas,
- the accelerating loss of our best agricultural land to urbanization,
- the prospect of global warming, which modeling studies indicate as likely to reduce crop yield,
- lack of incentives in Europe and North America to increase their already high average yields still further.

The changes of agriculture from a purely production-oriented activity into a science based production sector, trying to meet productivity, efficiency and efficacy aims has been of considerable importance during the last decades. Agriculture has broadened and diversified its objectives. The concept of a good agricultural practice, where farmers aim at an ecological and economical sustainable use of resources and farm management should be the guiding principle.

Currently, nutrient depletion occurs in many parts of Africa, due to the expansion of crop production on marginal soils without fertilizer use (Keulen, van & Breman, 1990). Farm households are confronted with deteriorating relative price relations between farm outputs and inputs, resulting in a net exploitation of soil nutrients. Given the socio-economic environment, farm households have limited options for investments in nutrient-adding or nutrient-saving techniques, which have been developed in many research centers. It is obvious that the complex problem of profitable and sustainable nutrient management, requires more than most of the currently on-going, mono-disciplinary and sometimes scattered research activities can offer. It is therefore necessary to integrate different relevant disciplines and scales, into a workable set of problem statements for targeting research and development. Nutrient monitoring is a multi-disciplinary and multi-scale approach, addressing the problem of soil nutrient depletion (Smaling & Fresco,1993; De Jager et al., 1998). It involves and aims at the various actors influencing soil nutrient management at different levels. A quantitative and qualitative diagnostic phase, to determine nutrient management and economic performance in existing farming systems, is followed by a targeted process of participatory development of Integrated Nutrient Management (INM).

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