Crop management in 2025.

Cretenet M., Fok M., Hau B., Vaissayre M.
CIRAD, Montpellier, France.

Strategic and tactical decisions guided by economic risks and environmental impacts …

- Imagining what cotton growing systems might be like in 2025 is a particularly uncertain exercise because of (i) climate patterns (global change) and erratic fluctuations in economic contexts (markets, subsidies, supply and demand), and (ii) uncertainty with regard to the progress of research (new technology) in the next two decades.
- However that may be, it is strongly probable that the contexts of uncertainty on international cotton fibre markets and the climatic "anomalies" now observed will not have been solved by 2025. Thus cotton growers, wherever they operate, will face this twin uncertainty of market and climate and will therefore have an increasing need to use risk indicators in decision making. This will apply in both the strategic choice of a fibre market segment and in the choice of cultural techniques during the farming season.
- Furthermore, the increasing segmentation of the cotton fibre market as a result of the production of organic cotton, fair trade cotton, genetically modified cotton and 'traditional' cotton, combined with the classification of the fibres marketed, will result in an increasingly broad range of potential marketing channels, forming so many opportunities for an informed grower.
- The environmental preoccupations underlying this market segmentation should increase under pressure from political leaders, civil society and consumers. The awarding of labels based on the reduction of environmental impacts related to the cropping system will result in specifications for growers that limit the options to a range of cultural techniques that varies according to the label; this will have effects on production potential and production costs.
- Growers will therefore have to make strategic choices among an increasing variety of opportunities and it can be considered that market information systems will develop strongly, especially via the Internet, to provide the aid expected by producers in strategic decisions.
- The possible technical alternatives and the development of coherent crop management sequences in tactical management decisions for cotton once the

strategic choices have been made (the sector segment targeted and the fibre quality chosen) are addressed here. We feel that the main trend in the evolution of crop management sequences in cotton growing should be greater mastery of the quantity and quality of the fibre produced in order to increase competitiveness in a given market segment. The questions underlying the coexistence of the different sector segments (organic cotton, genetically modified cotton, fair trade cotton and traditional cotton) in the same territory, and with dimensions related to politics and society may form the main dampener for this scenario.

Decision support systems for the management of increasingly complex farming systems …

- The diversity of environmental conditions (soil, climate, pests and diseases), of types of production (manual, draught cultivation, motorisation), of cultural techniques (varieties, tillage, fertilisers, pesticides, etc.) and of market segments goes beyond individual capacity for appraisal and requires the use of modelling in producers' decisions (Sequeira 1997; Keating 2003; Stöckle 2003).
- The interface between these biophysical models and the producer consists of decision support systems (McKinion 1988; Lemmon 1990; Hearn 2002; Hoogenboom 2003; Van Ittersum 2003) that incorporate a human component (the agricultural advisor) in smallholding cotton production zones.
- Such use of models will be all the more necessary as the criteria for the evaluation of cultural techniques and crop management sequences must (i) integrate economic and environmental risk indicators, and (ii) apply to scales larger than that of the field (farm, landscape unit, supply zone, region, etc.).
- The constraint for each type of producer to increase competitiveness to gain a foothold on the market will require a simultaneous rational approach to both the productivity and quality components of his production. The reasoning will make increasing reference to the production potential (yield and quality) specific to the situation of each grower. This spatial component of decision support refers to the 'precision agriculture' concept (Lowenberg-DeBoer 1999; McBratney 2005) that should therefore no longer be reserved for the most intensive farming systems.
- The production target chosen at the individual level will be compromises between economic margins to be maximised, risk levels accepted by the grower and the negative environmental impacts to be kept to a minimum.

Production potential and the evaluation of climate-related risks …

- The evaluation of production potentials in cotton growing in which climate (sunlight, precipitation and temperature) is the only constraint is essential information for the rational addressing of crop competitiveness. Reducing the climate-related potential by taking the soil constraints into account makes it possible to gauge the efforts to be made in soil improvement. These appraisals form the basic reference material for a rational approach to production objectives. Decision support systems will make it possible to specify at the scale of the grower what the 'suitability for cotton production' concept consists of - a concept developed at other scales for decision makers (politicians and planners) other than producers.
- Inter-annual climatic swings are a source of more or less marked variations in cropping performance, interacting with the crop management sequences used. It is important that the decision support systems intended for producers should make it possible to evaluate the resilience of crop management systems in long observed or generated series of climate data (Cretenet 2003).

Respect of the specifications of decision support systems requires substantial progress in soil science models …

- Soil is certainly the main determinant in plant cover heterogeneity. The accuracy and reliability of the decisions suggested by the system depend on the capacity of decision support systems to integrate such soil heterogeneity and hence crop heterogeneity. The techniques used in precision agriculture to address these relations between soil heterogeneity (Nielsen 2005) and crop response to this variability are an essential application here.
- Conversely, in terms of scale transfer, decision support systems will incorporate functions for the evaluation of runoff erosion risks, the risks of nitrate pollution of groundwater and fertility transfer from the sylvo-pastoral sector to the cultivated sector in terms of carbon, in particular via herds and flocks. The main expected 'innovation' in soil sciences is the taking into account of the geographic referencing of soil variables and data in decision support systems.
- Some of the essential functions for the development of choices in tillage, fertilisation, crop residue management, crop rotations or combinations of crops

and cover plants and the integrated management of soil biological pests (Hall 1996) have already been integrated in cotton growing models. Others are independent models or modules for model plants other than cotton and yet other are currently being developed. Our analysis is limited to mentioning several functions that we consider important for responding to producers' expectations with regard to crop management.

- With regard to the physical (Roger-Estrade 2000) and chemical components of the soil, it is necessary to integrate both (i) the functions of physical support for the crop, enabling the simulation of plant rooting and that of water flows in both rainfed (Braudeau 2007) and irrigated farming, and (ii) the functions that determine the mineral nutrition (N, P and K) of the plant (Claassen and Barber 1976; Scopel 2005). It must be possible to simulate tillage techniques combined or not with mulch, especially with regard to their impacts on water flows and also their interaction with weed management (Séguy 1999). The 'biological pump' effect in which nutrients are leached to a depth in the soil of certain crops combined with or rotated with cotton and soil acidification processes linked to certain fertilisers and aggravated by the leaching of exchangeable bases in the soil as a result of strong interaction with mineral uptake should be incorporated.
- As regards the taking into account of the soil biological component, soil biological activity (Spain 1992) in its interactions with the carbon and nitrogen cycle must be incorporated and thus make it possible to appraise both the mineralisation of soil organic matter during the cropping season, its cation exchange capacity (Balesdent 1996), that of soil structure stabilisation and its role in the long term in carbon sequestration by a cropping systems (Falloon 2002; Krull 2003). As soil organic matter plays a prime role as a component of soil fertility in the sub-Saharan cotton zones, this function will make it possible to appraise the sustainability of the cropping systems used there.

Characterisation of the 'agro-physiology functioning' of varieties …

- Expectations of plant models in terms of function concern the characterisation of the agricultural response of varieties to abiotic and biotic stresses. This response results from crop yield build-up processes and lint quality.
- Hence the aim of modelling heterogeneous plant cover determined by soil heterogeneity (see above) is also present in the varietal field, with the

determinants being competition phenomena (for light, water and minerals) both in intra-specific populations (reseeding, varietal mixtures) and inter-specific populations (crop associations, mixed cropping, alley-cropping, etc.).

- Furthermore, the aim of describing the 'agricultural functioning' of a field in terms of the technological characteristics of the lint produced will require the replacement of the functioning of the 'average plant' in most current models by representation of the 'population' (Cretenet 2003) to be able to take into account the determinism of the heterogeneity of the crop profiles within a field.
- To provide a partial answer to the questions raised by the joint existence of certain chains—organic farming and genetically modified cotton for example—and also to evaluate certain environmental impacts with regard to biodiversity in particular, the question of determinism and its varietal component in gene flows (Fargue 2003) should be incorporated in the decision support systems of the future.

Integrated pest management involving multiple scales in crop protection …

- Weed management in cotton systems should be included in decision support systems in 2025 and raises once again the question of the modelling of heterogeneous multi-species populations that may take allelopathy phenomena into account. This also concerns the introduction of cover plants in the integrated management of biological pests (Cook 2007).
- The advantage of mixtures of varieties with regard to the development of diseases in cereal growing (Finckh 2000) deserves *ex ante* evaluation in cotton growing using heterogeneous population models linked to models of the spread of pests or diseases.
- Such possibilities assume that cotton (variety) / boll worm pests (Nibouche 2007), pricking insects, bacteria and fungi are modelled with 3-D representation of the cover (Hanan 2003; Yan 2004) to make it possible to integrate the dynamics of the spread of biological pests and to locate damage to plants and its consequences for production quality. Such prospects also assume that the resistance and/or attractiveness characters with regard to the various biological pests are taken into account as cotton variety parameters.
- All the techniques used today in integrated pest management must be accessible in decision support systems. This assumes that models of pest populations

dynamics include relations between pests and beneficials and the degree of speciation within an agrosystem.

- These models of population dynamics of pests will also incorporate the parameters that depend on the gaining of resistance to xenobiotics (active insecticide substances and toxins expressed by transgenic cotton plants) according to the cotton cropping system used (Vaissayre 2006; Nibouche, Guerard et al. 2007) and the ecosystems in which they are set (the proximity of vegetable crops, natural ecosystems, etc.).

Transfer of knowledge in numerous fields to enrich farmers' expertise and guide agricultural policies …

- The main challenge to be taken up to attain the scenario mentioned is the assembling of knowledge in different scientific fields (soil science, physiology, biology, entomology, weed science, etc.) at different scales of space (organ, plant, population, cropping system, farming system, agrarian system, etc.) and time (day, 10-day period, season, year, decade).
- The ergonomics of the systems that enable cotton growers to gain access to this knowledge is an essential factor in the development and operational level of transfer. This interface between scientific expertise and farmers' expertise must take the social and economic contexts into account. A participative approach makes it possible to respond to the constraints of such exchanges (Bousquet 2002; Dawn 2003). Cotton growing in family farming should be the main beneficiary of this knowledge transfer process.
- The capacity of the system relating production by volume and quality to crop management sequences and their environmental impacts allowing objective evaluation of the costs of gaining sustainability for farming systems gives the tool an essential political dimension (Van Ittersum 2006).

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