Future Crops for Food, Feed, Fiber and Fuel

4F Crops

WP2 - Task 2.6 Cropping possibilities

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Introduction

As discussed in task 2.1, the allocation of an energy crop rather than another one should be based on the following factors:

- Ecology (area of origin, temperature requirements, water requirements, photoperiodic response, nutrients requirements, soil requirements);
- Biology (phenology, growing season, growing habit);
- Crop physiology (radiation use efficiency, water use efficiency, nutrients use efficiency);
- Agronomic aspects (years of cultivation, breeding activity, role in crop rotation, propagation material, abiotic and biotic resistance, mechanization).

In task 2.2 the following aspects were taken into account to give an overview of the possible crop rotations of the existing annual food crops and annual energy crops, or the only annual energy crops based on the final product (e.g. bio-oils and bioethanol): environment (temperature, precipitation, etc.), role of the crop in the rotation, avoidance of mono-cropping (pests and diseases accumulation), economic significance, management practices, increased crop yield, reduced soil erosion, improved soil structure (enhance permeability, biological activity), increased water and nutrients storage capacity, increased organic matter, rooting depth, climate change scenario.

As far as crop rotations are concerned, they relate to a temporal sequence of crops on a given cultivated land. The main rules are based on the fact that crops that deplete soil resources should be alternated with crops that replenish those resources. Rotation plans are usually built around one or two leading crops, followed by one or more legumes and/or other cash crops. It is important to include legumes in the rotation as they fix nitrogen contributing to soil fertilization, soil acidification, weed control when short season forage crops are cultivated and to forage and seed production.

More in general, cropping system is a wider concept which implies a community of crops and the relative management practices used to achieve this production with the aim to realize specific agronomic objectives, or in other words, the conjunction of the vegetal production of a given plot, including the space-time disposition of crops and the interaction between these and the resources of the farm, other farm activities and the physical, biological and technological factors (Borin and Ceccon, 2002). The prevailing economic situation, availability of agricultural equipments, availability of economic resources, markets and laws

are also important factors to consider when planning a cropping system. However, in the present task the only ecologic and agronomic aspects are taken into consideration while the other factors (economic, energetic, environmental, social, etc.) are analyzed in the subsequent work packages.

In particular, the aim of this study was to define different scenarios based on (i) seven climatic zones (Metzger et al,2005), (ii) two type of soil (marginal or agricultural), (iii) two level of input (conventional or reduction) and (iv) type of crop (annual, perennial, conventional and of new introduction).

(i) First of all, climate is the basic criterion for distinguish various unit of utilization and the suitability of different areas for different crops. The environmental stratification of Europe suggested by Metzger et al. (2005) was used in the analysis, assuming similar environmental parameters where agriculture land could be suitable for non-food crops cultivation along with food, feed and fiber crops.

(ii) The nature and quality of soil is a function of soil forming, climate factors, topography, parent material, soil biota and time; for this reason, it is difficult to distinguish between “agricultural” and “marginal”. According to McGee (1984), marginal soil is a very wide concept that could include several types and categories of soil and the marginality of soil could be ascribed to several factors such as water deficit, rainfall distributions, extremely hot or cold temperatures, lack of effective soil layer for rooting depth, soil with mechanical limitations because of large rocks, steep slopes, shallow or weathered. Moreover, the marginality of soils could be also linked to the economy and market oriented definitions, which implies that cultivation of marginal lands is justified only after a thorough assessment of the economic implications in term of input incurred as compared to the expected output (gross income minus production costs). For instance, land may be considered marginal for large scale mechanized crops, but of good quality for small scale non-mechanized farming, or vice-versa (Laker, 1978). According to Ludick (1998), a specific soil could be marginal for certain crops but of good quality for others. Example of poor rainfall and not well distributed during the crop growing cycle (e.g. South Mediterranean environments, with a mean annual rainfall of 550 mm concentrated during autumn-winter and prolonged drought summer) are conditions unsuitable for maize and/or other high input summer crops, while economical profitable for

winter crops, such as winter cereals, able to grow well and benefit of the water stored during winter period. On the other hand, improvement in cultivation techniques and other technological inputs such as new cultivars (drought resistant, pest resistant, etc), adequate weed and pest control could contribute towards production in marginal soil, and thanks to this marginal soils can become profitable.

(iii) Extremely important when determining the agricultural production potential of a land, is to specify the management or production systems which are applied to the specified objective. According to the Food and Agricultural Organization (FAO, 1983) a generalized description of the three different levels of inputs and management could be the follow:

1) High input level: methods applied at this level are based on advanced technology and high capital resources. Fertilizers, chemical weed and pest control used to achieve maximal yields or economic returns, as well modern mechanization methods. Appropriate soil conservation practices and ecosystem management, frequent exchanges with extension service and peers. Use of high yielding varieties and hybrids.
2) Intermediate input level: these are methods practiced by farmers who follow the advices of agricultural services but have limited technical knowledge and capital resources. Agricultural techniques and adequate input to improve crop yields, but not to achieve maximum yields or economic returns. Some fallow and soil conservations techniques are applied. Use of improved cultivars, chemical weed and pest control.
3) Low input level: this is usually rainfed condition. No significant use of input such as artificial pesticides and fertilizers or improved cultivars and machinery. Use of local cultivars, fallow periods practiced and low capital intensity with high family labor intensity and family based infrastructure. These are typical conditions of developing countries.

(iv) The choice of the crop and their suitability to the different European environmental zones have been already reported and discussed in task 2.1.

Methodology

In the present report we have organized in a hierarchy the following criteria:

1) climatic zones;

2) type of soil;
3) level of input;
4) type of crops.

1) *Climatic zones*. Seven bioclimatic areas characterized by maximum and minimum temperature (ºC), rainfalls (mm), number of months < 0 ºC, active temperature > 10°C and length of the growing season (days) were: Nemoral, Continental (combined with Pannonian), Atlantic North, Atlantic Central, Lusitanian, Mediterranean North and Mediterranean South were considered. Alpine North and South, Boreal, Anatolian and Mediterranean mountains were not analyzed due to the extreme severe temperatures, or the impossibility of growing species different of meadow or feed crops (see Annex I and II, task 2.1).

2) *Type of land.* Two type of soils were considered: agricultural and marginal. Agricultural land refers to a flat soil, characterized by the following traits: absence of rocks and stones, sand, clay and silt in optimal ratio (e.g. sand 30-50%, clay 5-10%, silt 10-15%, lime 1-5%, organic matter 2-5%), optimal macro-microporous ratio, depth (≥ 1.0 m), good drainage, pH (slightly acid to neutral), exchange sodium percentage (< 15%), soil salinity (< 4 dS m^{-1}), cation exchange capacity (> 20 meq/100g of soil), good content of macro and micro elements, rich in micro, meso and macro soil biota.
Marginal land is a very wide concept that could include several types and categories of soil and the marginality of soil could be ascribed when one or some of the aforementioned parameters are out of the optimal range, like for example soil with mechanical limitations because of stones, steep slopes, shallow or weathered, low organic matter content, etc.

3) *Level of input*. The input used in the present study were tillage, sowing/transplant, crop practices (fertilization, chemical and/or mechanical weed control) and harvest. Two different level of input were thought: high input level and low input level.
High input is based on the use of the present conventional resources (economic and energetic). Fertilizers, chemical weed and pest control are used to achieve maximal yields or economic returns, as well as modern mechanization methods with use of high yielding varieties and hybrids.

Low input level no significant or very low level of input, such as artificial pesticides and fertilizers and machinery are used.

4) *Type of crops.* The suggested crops could be divided into two groups: conventional ones commonly grown all over the EU and crops to be implemented as new in the existing farming systems. The conventional crops are: rapeseed, sunflower, soybean, sugarbeet, grain sorghum, maize, flax and hemp that are commonly grown as rotational annual crops for food, feed, and fiber. When used for non-food purposes their agroclimatic requirements should not be different from what they are when used for traditional purposes. The crops to be newly implemented in the existing farming systems include both annual and perennial crops (see task 2.1). Among annual crops were considered: sweet and fiber sorghum, ethiopian mustard, sufflower, kenaf. Perennial crops were split into two groups: herbaceous perennial (reed canarygrass, switchgrass, miscanthus, giant reed, cardoon) and woody perennial (willow, poplar, eucalyptus).

Choice of cropping system scenarios in Europe (Draft of results and discussions)

The information summarized in the following Annex gives an overview of the possible cropping systems scenario of the 4F crops (food, feed, fiber and fuels) and their potential feasibility based on biological interactions and adaptability to climatic and geographical areas of Europe at a macro-regional level. Generalized solutions are, however, not easy to be reported, therefore the choice of cropping systems that best fit with the specific area have been related to the geographical distribution, suitability to the climatic conditions, uses, and management practices; in other words, the potential feasibility of a cropping system scenario is given by the interaction of atmosphere-plant-soil and the subsequent crop-following crop interactions. Therefore, from the agronomic point of view the driven factors for crop management and choice of cropping system scenarios in European environment were: 1) climatic constrains, 2) energetic consumption, 3) crop practices and 4) harvest.

Furthermore, in the long-term the detailed information on management practices (e.g. tillage, irrigation, harvest time, available equipment, etc.) and their interactions with the specific conditions of a site, agronomic potential and environmental impact have to be considered as mutable and dynamic.

The choice and allocation of the crop have been reported in task 2.1, where the suggested crops have been divided into two groups; conventional ones, commonly grown all over the EU and crops to be implemented as new in the existing farming systems. A full description of the crop allocation in the different European climatic zones have been also reported by Krasuska et al (2010).

Regarding tillage operations the ordinary agronomic practices for each crop have been considered reducing the depth of tillage from high to low input. In order to obtain an optimal plant density in the agricultural land were used the data reported in the literature, while in marginal land, due to different limiting factors, the amount of seed/plantlets was increased. At the same extent, fertilizers, herbicides and pesticides were reported based on the environment considered and according to the scientific literature, European Fertilizer Manufacturers Association (EFMA, 2000) and Eurostat (The use of plant protection products in the European Union 1999-2003).

Energetic consumption for management practices have been considered the same irrespective of the environment, but decreasing from marginal high to agricultural low inputs (Cosentino et al., 2005). In marginal soils, the energetic consumption are higher than agricultural ones for one or more limiting factors which will surely penalize the production of the crops and increase the cost of mechanization. For this reason the level of input in same case were higher than conventional soil due to higher time of operations and higher fuel consumption.

Crop practices (amount and respective energetic consumption for distribution of fertilizers, herbicides and pesticides) decreasing from high to low input, both at seeding/transplant and top dressing (Cosentino et al., 2005; Fernando et al., 2010). Harvest of perennials were based on short rotation coppicing, with cutting every three years for woody crops (willow, poplar and eucalyptus), while for herbaceous perennials every year (swithgrass, reed canarygrass, miscanthus, giant reed and cardoon) (Zegada-Lizarazu et al., 2010). The yield of marketable products of annual crops refers to oil seeds and grain for oleaginous and sugar/starch crops, respectively, taking also into account the yield of lignocellulosic straw achievable after harvesting (e.g. straw of rapeseed, wheat, hemp and flax, and stover of corn and sorghum).

The agronomic aspects and input request by energy crops, both annual (oil and starch/sugar) and perennials (woody and herbaceous) have been also reported in Zegada-Lizarazu et al (2010), energetic and environmental by Rittenmaier et al (2010) and Fernando et al (2010). Moreover, the analysis has been conducted consulting the most relevant literature such as Faostat, Eurostat and DG Agriculture (2010), along with expert published

papers , reviews and final reports of previous European projects (Alexopoulou and Christou, 2003; Cardone et al., 2003; Copani et al., 2009; Cosentino et al., 1997; Cosentino et al., 2003; Cosentino et al., 2005a; Cosentino et al., 2005b; Cosentino et al., 2006; Ekin, 2005; Elbersen et al., 2004; Lewandowski et al., 2003; Mantineo et al 2009; Trnka et al., 2008; Van Dam et al., 2007; Venendaal et al., 1997; Fischer et al., 2005; FAIR 5-CT97-3701; AIR3-CT920041; AIR-CT92-0294; FAIR CT96-2028; FAIR CT98-3784).

From the analysis of all the studied factors was possible to indicate many different cropping systems for each environmental zone of Europe.

In each environmental zone is possible to suggest cropping systems which include both annual and perennial crops.

In Nemoral environmental zone we individuate two perennial cropping systems and five cropping systems characterized by annual food, feed, fiber and fuels crops:

- Cropping system 1: Willow
- Cropping system 2: Reed canary grass
- Cropping system 3: Pea – Cereal (barley) – Rapeseed
- Cropping system 4: Hemp - Rapeseed – Pea
- Cropping system 5: Rapeseed-Cereal (barley)-Pea-Rapeseed
- Cropping system 6: Rapeseed-Flax-Sunflower
- Cropping system 7: Red clover-Rapeseed-Flax

In Continental environmental zone we individuate two perennial cropping systems and six cropping systems characterized by annual crops:

- Cropping system 1: Poplar
- Cropping system 2: Miscanthus
- Cropping system 3a: Cereal (wheat)-Maize-Sunflower-Sorghum-Red clover
- Cropping system 3b: Pea-Maize-Sunflower-Sorghum- Red clover
- Cropping system 4: Flax-Cereal (wheat)-Pea
- Cropping system 5: Maize-Sugar beet-Sorghum
- Cropping system 6: Rapeseed- Flax- Sunflower
- Cropping system 7: Red clover-Rapeseed-Cereal (wheat)-Flax

In Atlantic North environmental zone we individuate four perennial cropping systems and six cropping systems characterized by annual crops:

- Cropping system 1: Willow
- Cropping system 2: Poplar
- Cropping system 3: Miscanthus

- Cropping system 4: Switchgrass
- Cropping system 5: Rapeseed-Cereal (barley)-Flax
- Cropping system 6: Hemp-Cereal (barley)-Pea
- Cropping system 7: Rapeseed-Pea-Wheat
- Cropping system 8: Rapeseed-Cereal (barley)-Pea-Rapeseed
- Cropping system 9: Flax-Wheat-Pea
- Cropping system 10: Rapeseed-Flax-Red clover

In Atlantic Central environmental zone we individuate three perennial cropping systems and four cropping systems characterized by annual crops:

- Cropping system 1: Miscanthus
- Cropping system 2: Poplar
- Cropping system 3: Switchgrass
- Cropping system 4: Sugar beet-Cereal (wheat)-Pea
- Cropping system 5: Rapeseed-Cereal (wheat)-Pea-Rapeseed
- Cropping system 6: Flax-Cereal (wheat)-Pea
- Cropping system 7: Rapeseed-Flax-Red clover

In Lusitanian environmental zone we individuate three perennial cropping systems and eight cropping systems characterized by annual crops:

- Cropping system 1: Eucalyptus
- Cropping system 2: Poplar
- Cropping system 3: Miscanthus
- Cropping system 4: Pea-Cereal (wheat)-Rapeseed
- Cropping system 5: Rapeseed-Cereal (wheat)-Hemp-Cereal (barley)
- Cropping system 6a: Wheat-Maize-Sunflower-Sorghum-Red clover
- Cropping system 6b: Pea-Maize-Sunflower-Sorghum- Red clover
- Cropping system 7: Rapeseed-Cereal (wheat)-Pea-Rapeseed
- Cropping system 8: Maize-Sugar beet-Sorghum
- Cropping system 9: Soybean-Ethiopian mustard-Sunflower
- Cropping system 10: Rapeseed-Flax-Red clover

In Mediterranean North environmental zone we individuate three perennial cropping systems and seven cropping systems characterized by annual crops:

- Cropping system 1: Poplar
- Cropping system 2: Miscanthus
- Cropping system 3: Giant reed

- Cropping system 4a: Cereal (wheat)-Maize-Sunflower-Sorghum-fallow
- Cropping system 4b: Legume (Pea)-Maize-Sunflower-Sorghum-fallow
- Cropping system 5: Flax-Cereal (wheat)-Pea
- Cropping system 6: Maize-Sugar beet-Sorghum
- Cropping system 7: Soybean-Ethiopian mustard-Sunflower
- Cropping system 8: Rapeseed-Flax-Safflower
- Cropping system 9: Sorghum-Soybean-Cereal (wheat)-Kenaf

In Mediterranean South environmental zone we individuate three perennial cropping systems and three cropping systems characterized by annual crops:

- Cropping system 1: Giant reed
- Cropping system 2: Cardoon
- Cropping system 3: Eucalyptus
- Cropping system 4: Ethiopian mustard-Cereal (wheat)-Legume (faba bean)-Sweet sorghum
- Cropping system 5: Faba bean-Cereal (wheat)-Ethiopian mustard-Sweet sorghum
- Cropping system 6: Flax-Cereal (wheat)- Legume (faba bean)

The low number of cropping systems suggested in Nemoral and Mediterranean South, as compared to the others, were due to the too cold temperature during the winter time in Nemoral and the high temperature along with summer drought in Mediterranean South. Furthermore, in the latest environment, in order to include some crops in the suggested cropping systems (e.g. sorghum) the use of water for irrigation is necessary.

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