

INTERCROPPING AND ALTERNATIVE FIELD CROPS AS ENVIRONMENTAL MEASURES

*Franc Bavec*¹

Abstract

The numerous interdisciplinary effects of applied ecological intensification after 2013 in EU should support sustainable environment. These measures can improve biodiversity, natural nutrient supply for crops, balances of energy, increase the number of niche organic products and incomes of small scale farms, sustain a more nutritional and healthy diet and support green-care for the well of humans. Based on a review the lack of environmental indicators, which influence also social and economical quality of indicator parameters at the field – farm level, a precise importance of intercrops, is noticed. Due to its many beneficial effects (crop diversity, nitrogen fixations by legumes instead of synthetic N fertilisers, weed suppression, yield stability, inter-specific complementarily, more efficient use of environmental sources, soil cover at under-sown crops, higher protein content in the seeds for grain feed or silage mixture especially important after BSE crises, etc.) inter-cropping represents a high valued strategy for long term sustainable plant production management. Because of the complexity of these systems, intercropping has been neglected in practice and just partly researched as a plant production system under European climate and cultivation circumstances. In spite of beneficial effects of intercrops on sustainable production and positive environmental impacts, especially on biodiversity, no financial supply in EU and OECD community for environmental measures - is it justified?

Introduction

During the recent years of European Common Agricultural Policy (CAP) Slovenian agri-environmental support based on Slovenian Agri-environmental programme (SAEP 2003-2006) and Agri-environmental payment (AEP 2007-2013) includes 22 and 23 measures, respectively, in comparison with other EU and OECD countries (Bavec and Bavec, 2011) it is a small number of agri-environmental measures. Widely AEP measures includes of crop rotation, greening of fields, organic agriculture, soil coverage in water protected areas, etc. Measures like greening of fields, soil coverages in water protected areas are important rules, however, due to the reality of climatic circumstances and agricultural measures they brought about stiff administrative rules and sometimes a lot of troubles for the farmers. But on the other hand they solve environmental and well-being problems very practically. According to the RDPS (2007) one of the most efficient ways for sustainable agricultural use of natural resources farming (Bavec et al., 2009a, b; Turinek et al, 2009) is organic farming, as it significantly contributes to the provision of public goods, preservation and improvement of biodiversity, preservation of drinking water sources, increase of working places, conservation of agricultural landscape and environmental protection. Furthermore, it ensures the production of healthy and high-quality food with high nutritional content. Organic

¹ PhD. Franc Bavec, Full Prof., University of Maribor, Faculty of Agriculture and Life Sciences, Pivola 10, 2312 Hoče/Maribor, franci.bavec@uni-mb.si

farming has the best possible impact on sustainable management of the renewable and non-renewable natural resources with a special mission to exerting the principle on adequate animal rearing, well human-being and promoting health. In this way organic farming represents the basic benefit for social change and real green care (Sempik et al., 2010; Dessein and Bock, 2010). According to the mentioned functions organic farming is the basic ecosystem service in agriculture with interdisciplinary functions for the whole chain (from biodiversity, to quantity and quality of food, regional transport, organic produced food in public kitchens, etc.), but the partial effects on environment can influence the individual agricultural measures under conventional or integrated cultivation systems (Bavec et al, 2009a).

Based on the report "Funding for Farmland Biodiversity in the EU" (Farmer et al., 2008) organic farming can be beneficial for biodiversity in some countries or regions, but this is not the underlying objective of supporting such as system. According to the European Economic and Social Committee (NAT/471) the importance of biodiversity maintenance has still not come to the forefront of political discussion and action. With the 2013 reform of agricultural policy, biodiversity maintenance criteria must play a major part in the CAP, in order to resolve the current conflict between economic production and nature conservation. But also in this new document (NAT/471) exists a lack of some actions between linear linked biotops, species and/or ecosystem services.

We can underline that the mission of organic farming is well established, according to mentioned facts, development of organic farming in Slovenia including extensive experiences from the farmers, professionals and scientists. In general, for an organic »greening« of the CAP a lot of lacks exist, because of very complicated administrative support, undeveloped processing and marketing systems, lack of use of organic foods in public kitchens and underdeveloped organic tourism, and »green« care in organic farms. Also field hedgerows and margin strips have many agronomic, environmental, human and wildlife functions, but they are very rarely involved as indicators into green CAP, and they are often in contradiction with organic farming rules, production and are cross-complying.

But primarily at the basic production level, the new very beneficial measures for a further development of »greener« CAP and associated positive interdisciplinary effects on environment and society should be taken into account. These measures are presented in the body of the paper below.

Beneficial use of alternative field crops

Intensive agriculture (and consequently organic farming) evidently reduces fields' biodiversity including the number of utilized crops and in consequence reduces natural health and nutritional compounds in the food. Introduction of alternative (rare, underutilized, disregarded, neglected, new and alternative GMO free) crops into the structure of field crop rotation can increase plant biodiversity and the nutritional and health value of food. Alternative crops are rich natural resources of essential amino acids, antioxidants, minerals, stimulators and other usable compounds, which are often limited to products from just a few main crops produced over the world. Production of underutilized crops shall help to increase resistance to plant diseases, predators, and helping us to produce food without synthetic pesticides (Bavec and Bavec, 2007). In this case, organic production of underutilized field crops represents a very important option for environmentally acceptable crop production and niche for special 'organic' products. The selling of this kind of products is of special interest for small scale farms, because it is a better solution compared to producing and selling cheaper products on global markets. But in this case the consumers, advisers and farmers

need professional knowledge about preferences of underutilized crops, production characteristics, clear guidelines for organic production, post harvest technology, food processing including product certification and clear marketing strategies. Also support done by educational, research and governmental institutions should be in accordance with these needs. Every specific possibility and activities of each country can influence the consumer-producer relationships and effective marketing by specific or/and niche products based on underutilized crops (Williams and Hag, 2002; Bavec et al., 2009b).

Edible underutilized field crops encompass cereals and pseudocereals including millets, pulse crops, root and tuber crops, oil seed crops and dyes, some of which (including fibre crops) are usable for creating new market niches based on small scale production and processing. Furthermore, some of them are also suitable for industrial processing. Depending on country, some of these plants are indigenous, based on spread secondary diversity are completely new, sometimes exotic. Understanding and use of underutilized crops is based mainly on tradition and specifics of their growth circumstances. Most of them are unknown to a great percentage of agronomists. But the interest for underutilized crops is increasing also with publishers, because during the last decades a few publications spread the knowledge about underutilized field crops (Duke and duCellier, 1993; Williams, 1995; Belton and Taylor, 2002) with special attention to temperate climate (Bavec and Bavec, 2007).

For example in Slovenia temperate climate circumstances dominate, just a small part is Mediterranean. For those the tropic crops should be introduced into temperate climate with special attention to growth period less than 160 frost free days such as for genotypes of sweet corn (*Zea mays* L. var. *saccharata*), batata (*Ipomea batata* L.) and other tropical tuber crops, specific genotypes of grain amaranths (*Amaranthus* sp.), quinoa (*Chenopodium quinoa* L.), groundnut (*Arachis hypogea* L.), vinas (*Vigna* ssp.), etc. The next factor is a system of reproduction based on plant parts growth in greenhouse conditions during winter time like in the case of batata. Well adopted spelt (*Triticum aestivum* L. ssp. *spelta* MacKey) to the temperate climate was forgotten, however introduced into crop rotations in every organic farm with field crop production during the last decade. Other farro group cereals such as einkorn (*Triticum monococcum* L.), emmer (*Triticum dicoccum* L.), etc. are introduced into organic farming just like sample crops on few farms. Buckwheat (*Fagopyrum esculentum* L.), proso millet (*Panicum milliaceum* L.) and oil seed pumpkins (*Cucurbita pepo* L. Group Pepo) were traditional, but neglected until the last decade when their production started to increase. The group of alternative oil crops such as false flax (*Camelina sativa* L.), safflower (*Carthamus tinctorius* L.), garden poppy (*Papaver somniferum* L. ssp. *somniferum* Kadereit) are being researched and considered for eventual introduction into crop rotations. We are also looking for some legumes and the group of millets from Africa - potential crops for dry conditions described by Bavec and Bavec (2007).

Traditional cropping systems of undeveloped countries contain numerous genotypes of domesticated crop species, as well as their wild relatives. The richness of plant biodiversity of traditional agroecosystems is comparable with natural systems. It is a reason why underutilized crops have to play a greater role in organic farming. Underutilized crops bring diversity into crop rotations and provide new possibilities for soil cultivation. Organic farming, which is based on traditional farming systems, offers a way of promoting diversity of diet income, minimization of risk, reduced insect and disease incidence, efficient use of labour, intensification of production with acceptable resources, maximization of returns and stability under responsible technologies. Underutilized crops help local communities being more independent, while use the local resources for production and reduces transport expenses. A similar pathway might be used also for organically produced underutilized crops (Dixon et al., 2007). The use of underutilized field crops has resulted in product competitiveness, rich nutritional and health value of food, tradition, locality, special quality

according to organic production guidelines and even market attractions. The health and nutritional rich products, especially if they are produced according to organic farming guidelines, represent a special niche in the market of the developed world.

Knowledge about food health and nutritional attributes based on underutilized crops is very useful for promotion, decision support for producers and for motivation of consumers for buying products. Special attention needs to be given to antioxidants in food (tokoferols in oil crops, squalen in grain amaranths, anthocyanins in sweet potato, etc.), rich amino acid compositions (grain amaranths, quinoa, partly buckwheat, partly legumes, etc.), gluten free foods for people with celiac disease (buckwheat, grain amaranth, quinoa, millets), quality fibre food (whole grained spelt and other cereals), rich food in minerals, vitamins or their good balance, etc. Many of them are used in pharmacology and alternative medicine, like oil seed pumpkins (Zuhair, et al. 2000), buckwheat (De Francishi et al., 1994; Li and Zhang, 2001; Krkoškova and Mrazova, 2005), amaranths (Rangajaran et al., 1998, Prokopowicz, 2001), etc.

The above information shows a very interdisciplinary tool among alternative field crops, which can help to change the structure of crop diversity with clear influences towards a better social and economical behaviour.

Intercropping – unexploited beneficial measure

Due to its many beneficial effects like crop diversity nitrogen fixations by legumes (Hauggaard-Nielsen, 2007; Bergkvist et al., 2011; Lithourgidis et al., 2011) instead of synthetic N fertilisers, weed suppression, yield stability, inter-specific complementarity, more efficient use of environmental sources, soil cover at under-sown crops, higher protein content in the seeds for grain feed or silage mixture especially important after BSE crises, etc.) inter-cropping represents a high valued strategy for long term sustainable plant production management. Because of the complexity of these systems, intercropping has been neglected in practice and just partly researched as a plant production system under European climate and cultivation circumstances. Especially in case of intercropping impacts on environmental impacts the research is deficient (Shili-Touzi et al., 2011).

Farmers and researchers carry out different cropping systems to increase productivity and sustainability by using crop rotations, relay cropping, and intercropping of different annual crops. Associated culture often involves cereals with legumes due to its advantages for soil conservation, weed control, lodging resistance, yield increment, hay curing, forage preservation over pure legumes, high crude protein content and protein yield. Different seeding ratios or planting patterns for cereal-legume intercropping have been practised. Bean yields in an intercrop culture are usually less than those obtained from sole bean stands. It is possible that yields be increased with suitable management practices such as the use of optimum plant population and improved bean cultivars. However, bean yields under intercrops represent a surplus to the main maize crop yield. In EU countries, cowpea is rarely used in intercropping with cereals in small-scale farms. A number of indices such as land equivalent ratio, relative value total and monetary advantage have been proposed to describe competition within and economic advantages of intercropping systems (from unpublished review, Bavec et al., Univ. Maribor). However, such indices have not been used for climbing bean (*Phaseolus vulgaris* L.) and maize intercropping to evaluate the competition among species and also economic advantages of each intercropping system.

Intercropping of climbing bean and maize is a common production system on small scale farms and of interest for research in the Latin America, as well as in South Africa, Ethiopia and other African countries. In temperate climate, this type of intercropping has been

practised traditionally 30 years ago, also in small-scale farms in Slovenia, Romania and in other Middle and East European countries. Despite the fact that intercropping systems should involve integrating crops using space and labour more efficiently, the recommendations supported well sole cropping systems, where also net incomes are higher.

In Slovenia, just one case of conversion from manual to mechanized production system of intercropped bean and maize production was established on approximate 4 to 6 ha per year in (farm Jankovič, Vihre/Krško), where the seeds of bean are used for silage for ruminants and partly for human nutrition. Also in other European countries we practically lost this traditional production system, although it still exists in some poor and self-sufficient small-scale farms, with some attention to the dry climate due to it changes (Baldy and Stigter, 1997).

In general, important benefits of intercropping cereals with legumes are the following: more available nitrogen due to nitrogen fixation with legumes - with up to 84 % of nitrogen may be derived from fixation by climbing bean, maize and bean intercropping may help converse a deficiency of bean production in European countries, in that it involves integrating crops using space and labour more efficiently, efficient competitions of cereals with weeds, improved soil structure, reduced loss of plant nutrients, less damage of plants to pathogens and insects, especially under organic farming systems. Based on available literature, most researches have been focused on intercropping of bush bean in non European growing conditions. Because of different canopy characteristics of bush bean data for bush bean are not comparable for climbing bean maize intercropping (only Gebenyahu et al. 2006). However, there is lack of scientific relevant information about promising plant ratios of maize-climbing bean intercropping systems especially produced in European temperate zones under integrated or organic production systems.

In this paper we want to focus attention to two additional reasons of proposed intercropping climbing bean/maize in temperate climate vs. marginal regions for maize (to FAO group 400) production (Bavec and Bavec, 2002) which are suitable also for growth of climbing bean due to temperatures and humidity, because of possible simple and environmentally friendly production. In this case the soil preparation is conventional (ploughing in autumn, pre-sowing soil preparation in spring), for sowing the same machine is used for maize and bean seeds, the bean seeds need to be sown close to the maize strips at maize stage of few true leaves after 1st or 2nd inter-row mechanical hoeing, close to the strips of maize plants. Also for harvesting maize silage combine is used, but for seed harvesting it might be harvested with a cereal combine and eventual separation of the bean and maize seeds could take place. The second benefit is production of rich silage in proteins because of bean grains, which contain approximately 20% of crude proteins. These kinds of proteins are good and might be relatively cheap replacement for animal sources of proteins, which are not allowed for ruminants feed after appearance of BSE - 'mad cow disease.'

In cereal-legume intercropping, cereal crops establish uniform canopy structures than legume crops and the roots of cereal crops grow to a greater depth than those of legume crops with less lodging consequences (Kontturi et al., 2011); but also agronomic traits of genotypes needs to be well adapted to intercropping. Climbing bean cultivars needs specific adaptation to intercrops using predominant morphological maize types grown in the area (Gebeyehu et al., 2006). Somewhat shorter maize plants can give improved net income when intercropped with climbing bean, provided they are resistant to stem lodging. This indicates that the component crops probably have differing spatial and temporal use of environmental resources such as radiation, water and nutrients. Therefore, this cropping system may help improve productivity of low external input farming, which depends largely on natural resources such as rainfall and soil fertility. The intercropping productivity is largely dependent on planting date and plant population of its components. Small-scale farmers have practised traditional cropping

techniques, such as intercropping, in which they unknowingly manipulate the plant population (Bavec and Bavec, 2002), because interspecies competition between plants become stronger.

Only in one EU research programme a survey was carried out within five European countries with regard to the practice of cereal grain legume intercropping. The mostly given combination was spring barley-spring pea beside 27 other combinations between pulses and cereals. 72 % of all examples consisted of spring varieties, the rest of winter varieties, mainly a special case of the French South West with mild winter climate. Intercrops were mainly used for feeding purposes. Best experiences were named as better yield stability, effective weed suppression, and good quality of feed. Of the negative experiences complicated mechanical weed regulation, unequal maturation and additional costs for separation were mostly named. The interviewed farmers showed predominantly positive prospects for the development of intercropping on their farms, problems with sowing techniques were of only importance (von Fragstein und Niemsdorff, 2008).

Based on the facts in this chapter, we can once again underline the importance of use of well known (Willey, 1979) and new beneficial intercropping effects on productivity and biodiversity in different the farming systems. Because the fact that intercropping is more expensive and complicated cultivation than sole crop production, intercrops need wider support (like new research and simulation models – Tsubo et al., 2005) that will be included into farming systems as a basic environmental measure at field production level.

Hedgerows and margin strips as additional value

Field hedgerows and margin strips have many agronomic, environmental, recreational and wildlife functions. The effectiveness of hedgerows and margin strips associated with organic farming is higher in comparison with conventional, because no chemicals are used, which reduce populations of natural species. On the other hand beneficial effects are shown through better pollination, positive effects of predators and behaviour of numerous wild animals. Due to different country and regional attentions to this measure, the CAP should bring the minimal standards for these measures for farming systems - especially for organic production, and also the minimal areas and subsidies for hedgerows and field margins need to be decided, and its need to be in accordance with cross compliance measures.

Conclusions

Future of »green« agriculture depends on initial ideas and development of organic farming, which is the only real promoter and the mirror for other production systems, when it comes to the question on how to manage agriculture more sustainably. The ecological intensification of agriculture depends on simple and clear ecological oriented CAP, which will not support the partly »green washing« of conventional agriculture or »conventionalisation« of organic farming. The basic principles for the development of »green« oriented agriculture at the field level are additional to official supported measures based on payments in order to promote crop biodiversity to include more alternative crops, intercrops including better support for hedgerows and margin strips. Intercropping has a many agronomical and environmental beneficial effects, which are very often described in research papers, mainly for Asian and African environmental conditions. Especially, because of climate changes, the alternative field crops and intercrops needs more political support under temperate climate and must be taken into account in EU CAP, and OECD policy like a part of environmental payments.

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