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The role of agroecosystems diversity towards sustainability of agricultural systems

YANKA KAZAKOVA-MATEVA¹, DONKA RADEVA-DECHEVA²

University of National and World Economics, Economics of Natural Resources Department
Sofia, Bulgaria

¹ *E-mail: yanka.kazakova@gmail.com*

² *Corresponding author, e-mail: donka.radeva@unwe.bg*



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Abstract

One of the major challenges of this millennium is ensuring food security in times of climate change, increasing population, environmental needs, economic and energy crisis. These challenges can be addressed by ensuring the sustainability of agricultural production systems and the necessary agroecosystems diversity in the form of integration and proper combination of crops, trees, animals, soil and water (Elkington and Hailes, 1988, Shiva, 1992).

This study aims to review the existing scientific knowledge about agroecosystems diversity, agroecology, traditional and alternative farming systems based on permaculture and biodynamical principles. It is based on literature review, whereby analysis and synthesis as scientific methods are used to: 1) discuss and summarize current findings on the role of agroecosystems diversity on the sustainability of agriculture; 2) evaluate the "state of the art" pointing out research needs for mainstreaming and scaling up agroecological approaches; 3) conclude on the future developments and certain actions needed at local, national and European levels to adapt agricultural practices towards sustainability of agricultural systems. Our findings reveal that the adoption of the principles of diversification of crops, trees and animals increases both the resilience of farms to climate change and environmental pressures, and improves their economic results via low-input decisions and stability in yields. At the same time, promoting and mainstreaming agroecosystems diversity across farms and regions in Europe requires targeted and simultaneous actions at the local, national and European levels both in terms of institutional and policy support and development of markets.

Keywords: Agroecology, Agroecosystems, Diversity, Sustainability

Introduction

One of the major challenges of this millennium is ensuring food security in times of climate change, increasing population, environmental needs, economic and energy crisis. These challenges can be addressed by ensuring the sustainability of agricultural production systems and the necessary agroecosystems diversity in the form of integration and proper combination of crops, trees, animals, soil and water (Elkington, Hailes, 1988, Shiva, 1992). Agroecology as a science, a set of principles and practices, and a social movement (Wezel et al., 2009) gains momentum in the last decade as the response to these challenges. The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) assesses the global food systems and concludes that "business as usual" is no longer an option. The IAASTD recognises that in agriculture, "there is most often a continuum between a farming system and a natural ecosystem, as the term agroecosystem indicates, and that farmers have a pivotal role as managers and stewards of these systems". The IAASTD Global Report advocates the use of agroecological approaches in policy, research and innovation, training, farm practices and other sustainability initiatives to address "the complexity of the agricultural systems within their diverse social and ecological contexts". The United Nations (UN) Special Rapporteur on the Right to Food highlights agroecology as a viable approach for working towards food security and recommends governments to implement public policies supporting the adoption of agroecological practices (De Schutter, 2010). In the final report of his mandate, De Schutter (2014) underlines the "enormous potential of agroecology" for moving towards sustainable modes of agricultural production and thus for future food security. In 2014, the Food and Agriculture Organization (FAO) hosted an International Symposium on Agroecology for Food Security and Nutrition, which "has opened an

alternative window within the FAO Headquarters, the ‘Cathedral of the Green Revolution’ (closing remarks, Director-General of FAO, 2014). The Director-General of FAO indicated that “the paradigm of the Green Revolution is showing weaknesses” which motivated the search of alternatives. He also presented agroecology as a “promising option” to increase productivity, improve resilience and make more efficient use of natural resources (FAO, 2014).

The most commonly used definition of agroecology is “the application of ecological concepts and principles to the design and management of sustainable agroecosystems” (Gliessman, 1998). Silici (2014) summarises the core principles of agroecology as (1) Planning, whereby the agroecosystem is regarded as one, and its health as a whole is valued more than the productivity of single crops. Furthermore, the farming system’s productive potential is harmonized with the physical limits of the surrounding environment; (2) Minimising the use of external resources and optimising the use of nutrients and energy on the farms; and (3) Field and landscape management promoting diversity of species and genetic resources, and functional biodiversity (natural enemies, antagonists, etc.) to enhance beneficial biological interaction and synergies among the components of agro-biodiversity and the associated ecological processes and services. These agroecological principles inspire a variety of farming practices such as conservation tillage, crop rotation and fallowing, cover crops and mulching, mixing crops in a single plot, mixed crop-livestock systems, integrated nutrient management, efficient water harvesting, agro-forestry, holistic landscape management, etc. As Silici (2014) explains these practices can be used in different combinations – from applying only one practice to a set of several practices. According to Silici (2014), farming methods such as permaculture or biodynamic agriculture largely apply all the agroecological principles.

There is a consensus in literature that agroecology is most adapted to and adopted by small-scale farms (IAASTD 2009, De Schutter 2010, 2014, Altieri et al. 2012, FAO 2014,). Altieri et al. (2012) recognize that managing complex and synergistic systems is easier in small farms because they are labour intensive and because labour is very productive. D’Souza and Ikerd (1996) conclude that from “a sustainability perspective, the smallest effective size will be the most competitive size for farms”. FAO (2009) and World Bank (2007) publications emphasize the role of small-scale agricultural production systems as the main source of food and income for the world’s poorest people, hence, their crucial role for addressing global poverty reduction and achieving food security objectives. Altieri et al. (2012) go further by stating that the only agricultural system that will be able to confront future challenges is one that will exhibit high levels of diversity, productivity, and efficiency.

Motivated by the significant potential of agroecology for responding to global changes and the positive role of small-scale farms within it, the current paper assesses agroecosystem diversity experiences and case studies around the world.

Methodology

This study is based on literature review. Analysis and synthesis as a scientific methods are used to: 1) discuss and summarize current findings on the role of agroecosystems diversity on the sustainability of (small-scale) agriculture; 2) evaluate the "state of the art" pointing out research needs for mainstreaming and scaling up agroecological approaches; 3) conclude on the future global developments and certain actions needed at local, national and European levels to adapt agricultural practices towards sustainability challenges.

Results and discussion

Agroecosystems diversity and diversification terminology

Gliessman compares the properties of natural ecosystems, sustainable agroecosystems and conventional agroecosystems at the farm scale, based on which he derives a general principle that “the greater the structural and functional similarity of an agroecosystem to the natural ecosystems in its biogeographic region, the greater the likelihood that the agroecosystem will be sustainable” (Gliessman, 2006). The maintenance of agroecosystems diversity in the form of spatial and temporal arrangements of crops, trees, animals and associated biota becomes a basic attribute of agricultural sustainability (Altieri and Nicholls, 2004, Gliessman, 2006). Such level of high plant and animal biodiversity is very typical for the traditional farming systems and for the so called in science “alternative low-input” agricultural systems, performing under permaculture and biodynamic principles.

The use of the term “diversification” in agriculture, permaculture and biodynamic agriculture can be confusing. In the literature, Emrys and Ngau, (1991) identify two forms of diversification: farm diversification, which is linked to crop diversification, and farm income diversification, which is related to the diversification of on-farm activities. The difference between the two is explained by the nature of the activities. According to Ilbery (1991), whereas farm diversification is located within the farm and implies primarily activities in the agricultural sphere, diversification of activities refers to income diversification coming from activities undertaken inside and outside the farm. Shome (2009) separates diversification in three categories: 1) employment diversification - a shift of labor from farm to non-farm activities; 2) crop diversification - a shift from a less profitable crop to a more profitable one; and 3) resource diversification – the use of resources in diverse but complementary activities.

Crop diversification is in the focus of agroecology since its emergence as a scientific field in the beginning of 20th century. Singh (2000) distinguishes between 1) horizontal crop diversification; and 2) vertical crop diversification. In the vertical crop diversification various downstream activities are undertaken. The main form and commonly understood concept of horizontal crop diversification is the addition of more crops to the existing cropping system (Delgado and Siamwalla, 1999). Multi-cropping, also referred to as intercropping or mixed cropping, is the agricultural practice of growing multiple crop species simultaneously in the same field for a significant part of their life cycle (Vandermeer 1989; Lithourgidis et al. 2011). Mixed cropping can be applied to field-crop species, pasture species, trees, or a combination of them. Tree-based intercropping systems represent alleycropping or agroforestry (Ehrmann, Ritz, 2014). Intercropping is further described as a system where available space between rows is used by different crops to allow maximum use of the soil moisture (Iglesias et al. 2006). Other authors describe the terms and conditions of species combinations in five main types (Malézieux et al. 2009; Vandermeer 1986): row intercropping, alley crops or strip intercropping, mixed cropping, mosaic intercropping and relay/sequential crops. These types combine perennial and annual plants in various configurations and for cycles of varying duration and multiple uses in all continents (Barral and Sagnier 1889).

In our paper, we focus on literature sources, where the term “diversification” is used in the meaning of crop diversification or horizontal crop diversification, which is largely adopted by the permaculture and biodynamic agriculture.

Permaculture is defined as “a method of establishing permanent, self-sustaining systems of agriculture, adaptable to both rural and urban locations, designed to produce an efficient, low-

maintenance, optimally productive integration of trees, plants and animals, structures and human activities within a specific environment” (Elkington, Hailes, 1988). Permaculture is also described as an alternative agricultural system where plants, animals, and humans are integrated into the ecosystem and supports each other’s functionality (Mollison, Holmgren 1978). Permaculture strategies include increasing biodiversity, mimicking ecosystem structures, building “guilds” of organisms that mutually support each other, and adapting to stages of plant succession (Jacke, Toensmeier 2005). In permaculture all the factors are capable of being manipulated to provide the overall best effect in such a way, that the most efficient outcomes can be maintained through simple design and management. (Richardt, 1995). Permaculture is usually seen as a method practiced and "most suited to small subsistence communities such as those espoused by some alternative life-style groups in the West" (Tisdell, 1991).

Ferguson and Lovell (2013) describe permaculture as (1) as a movement, notably advocating and implementing the development of diversified farming systems, and (2) as a design system and best practices framework. He states, that despite its increasingly high international and domestic profile, permaculture remains isolated from scientific research. Ferguson and Lovell, (2013) indicate the main reasons for scientific isolation of permaculture and namely “a lack of scholarly research about permaculture and neglect within the permaculture literature of contemporary scientific perspectives. The difficulty of providing a clear and distinguishing description of permaculture can cause confusion and hinder rigorous and systematic discussion.” Mulik (2015) also concludes in his research that one of the barriers to adoption of the sustainable farm systems is the lack of publicly funded research to improve and expand modern, sustainable food and farm systems.

According to Hathaway (2015), permaculture is the most widely practiced form of agroecology, which also provides an “ethical framework and principles that serve as a basis for discerning actions that enable the design of diverse, sustainable systems suited to a wide variety of cultural and ecological contexts”. Ferguson and Lovell, (2013) expand that in some cases, permaculture is broader than agroecology since it may be understood as both a movement and philosophy promoting design principles that can be applied beyond agriculture.

In this paper, we use the term “permaculture” in its main context of sustainable agriculture and a design system approach in agroecology, dedicated to produce ecological food in diversified agricultural systems.

Biodynamic agriculture represents a series of holistic management practices that address the environmental, social, and financial aspects of the farm, where the emphasis is placed on the integration of crops and livestock, recycling of nutrients, maintenance of soil, health and wellbeing of crops and animals; and where the farmer is part of the whole system (Diver, 1999). Biodynamic agriculture is inspired by the work of Rudolf Steiner and especially on maintaining: 1) sustainable soil fertility and 2) the relationship between plant growth and cosmic rhythms. Biodynamic agriculture stresses a holistic, spiritual understanding of nature and human life and thus aims at self-sufficiency in compost, manure, and animal feed, with little minimal external and nonnatural input. The key note of biodynamic agriculture is preservation of ecological diversity (Thompson et al., 2014).

Biodynamic agriculture became subject of research efforts during the past decades, despite being marked as dogmatic and looked with skepticism from part of the scientific community. According to a review of authors (Turinek et al., 2009), a fair share of the available peer-reviewed research results of controlled field experiments as well as case studies show effects of biodynamic preparations on yield, soil quality and biodiversity. They describe biodynamic farming as a method striving for diversified, resilient and ever-evolving farms, which could

provide ecological, economical and physical long-term sustainability for humankind (Turinek et al., 2009).

Agroecosystems diversity and climate change

The question about diversification of agricultural systems is increasing its importance because the majority of world's arable land is under monoculture systems, which are particularly vulnerable to climate change. This is true even for some large organic monoculture fields. The studies reviewed assess the energy saving and soil resilience effects from crop diversification. A study in Bangladesh (Rahman, Kazal, 2015) examines whether crop diversification provides economy in energy use. Rahman and Kazal use a large survey of 2075 farms from 20 sub-districts of 17 districts in Bangladesh. The results demonstrate economies of energy use in the diversified farms. These energy economies are in alliance with one of the basic principles in permaculture designed farms - "catch and store energy" through increased usage of renewable energy sources and closing the production cycle via implementing no-waste principles within the farm. Furthermore, 59.6% of total energy inputs in the country are renewable, implying that the farming systems in Bangladesh are not overly dependent on non-renewable sources of energy. The main policy implication of this study is that Bangladesh should pursue crop diversification, but needs to choose enterprise combinations strategically (Rahman, Kazal, 2015).

Multi-cropping approaches in production systems have benefits of increased production, effective pest, disease and weed control, and improved soil health. Ehrmann and Ritz (2014) review the effects of temperate arable multiple-crop systems on below ground processes within the plant-soil system. The results suggest that detrimental effects on crop growth can be minimised by appropriate management practices. The key is to be able to plan, prescribe and control crop mixtures to maximise overall crop performance and retain or enhance resilience of soil functions. Ehrmann and Ritz (2014) report numerous studies with yield advantages in mixed cropping systems compared to single crops, which include 1) more efficient and complementary use of available resources and niches; 2) facilitation via the roots; 3) enhanced soil fertility by intercropping nitrogen-fixers; 4) increased resilience against pests and diseases; 5) increased abiotic stress resistance due to higher levels of functional diversity within the system. These are serious advantages towards sustainability and climate change. According to the authors, this will require a paradigm-shift and a more integrated approach in designing crop production systems. Permaculture, which in its essence is an integrated system for design in agriculture, if applied properly in the agricultural systems could respond to the requirements of this "new paradigm". Turinek et al. (2009) point out biodynamic farming practices, where they indicate a more resilient, diverse and efficient system, as gaining importance in the face of increasing climate change, energy scarcity and population growth.

Case studies from Cuba, Brazil, Philippines, and Africa (Altieri et al., 2012) demonstrate how the agroecological development paradigm based on the revitalization of small farms, which emphasizes diversity, synergy, recycling and integration, proves to be perhaps one of the only viable options to meet present and future food needs. Agroecological systems are deeply rooted in the ecological rationale of traditional small-scale agriculture, representing long established examples of successful agricultural systems characterized by a tremendous diversity of domesticated crop and animal species maintained and enhanced by ingenious soil, water, and biodiversity management regimes, nourished by complex traditional knowledge systems. According to the authors, these "traditional agroecosystems have the potential to bring solutions to many uncertainties in an era of climate change, energy and financial crisis" (Altieri et al., 2012). The researchers reveal that the full organic farmers in the Philippines have considerably higher on-farm diversity, growing on average 50% more

crops than conventional farmers, better soil fertility, less soil erosion, increased tolerance of crops to pests and diseases, and better farm management skills (Altieri et al., 2012).

A literature survey by Petersen and Weigel (2015) addresses questions at all relevant levels of agrobiodiversity and the resilience to climate change with a focus on the temperate climate zone. According to the authors less than 15% of the approximately 1000 studies found provided relevant data that directly linked aspects of agrobiodiversity to crop yields under conditions of weather extremes or highly variable weather conditions. Roughly 45% of the relevant studies addressed small-holder agricultural systems in the tropics or subtropics. The authors claim that these systems differ markedly from the more industrialized agricultural systems in central Europe with respect to farm structures. Drought stress events were clearly dominating the studies, while heat stress, intense rain and flooding were hardly addressed. The data provide evidence that in the low-input agricultural systems of the tropics and subtropics a high diversity of crop species and a high species diversity exist. They found very few studies in the temperate zone with its highly industrialized agricultural systems, which have also addressed the relationship between agrobiodiversity, climate change and extreme events and could not draw on consistent information. The authors indicate that the first studies from this perspective come from France, where water usage efficiency in agroforestry and humidification in case of drought is already studied (Petersen, Weigel, 2015).

Agroecosystems diversity and economic effects

In this part of the paper, we review the literature on the economic effects, both positive and negative, of agroecosystems diversity around the world.

A study about agroforestry systems in Ghana (Ofori-Bah, Asafu-Adjaye, 2011) analyses whether and to what extent crop diversity affects productivity on cocoa farms. It also examines whether there are economies of scope (cost complementarities) from the sharing of farm inputs by crops on the same plots. The results indicate that diversified (multi-crop) cocoa farms are more efficient than single (mono) crop farms. The estimations for the economies of scope parameter indicate possibilities for cost complementarities between production of cocoa and other crops on the same plot. Ogundari (2013) estimates that diversification of crop enterprises enhances the technical efficiency level of farmers in Nigeria. Economies of scope theory could be connected to permaculture. Richardt (1995) indicates that permaculture is economical in the medium to long term, but perhaps not so in the short-run, because of the high costs of establishing a productive practice.

Chappell and Lavalley cite studies demonstrating, that small farms using alternative agricultural techniques could produce enough food to sustain human population, without increasing the agricultural land base. FAO (2014) reports that in most countries small and medium size farms tend to have higher agricultural crop yields per hectare than larger farms, but labour productivity is lower. Moreover, research clearly show (FAO, The State of Food and Agriculture, 2014) that small-scale farming, especially using “organic” methods may be two to four times more energy efficient than large conventional farms.

Gliessman (1998) states that integrated farming systems where small farmers produce simultaneously grains, fruits, vegetables, fodder, and animal products out-produce yield per unit of single crops on large-scale farms. Yield advantages can range from 20% to 60%, because polycultures reduce of losses due to weeds, insects, and diseases, and make a more efficient use of the available resources of water, light, and nutrients. In the example about Cuba - family farmers produce over 65% of the country's food, on only 25% of the land (Rosset et al. 2011). No other country in the world has achieved this level of success with an extremely low dependence on fossil fuels. They were inspired by permaculture activists in the country, but the success is influenced by the strong political support in this direction. This is an evidence that permaculture creates highly efficient and self-sustained productive systems

by imitating ecosystems (ECOS 2007). Mollison (1988) states that it was the first method for conscious design of artificial ecosystems that possess the productivity and benefit of conventional agricultural systems combined with sustainability and self-serving features of natural ecosystems.

Researchers report that full organic farmers in the Philippines have considerably higher on-farm diversity, growing on average 50% more crops than conventional farmers, and have net incomes per hectare one and a half times higher than those of conventional farmers (Altieri et al., 2012).

A study about biodynamic farms was carried out in Germany for an average duration of 14.5 years (6 to 51 years) and an average size of 28 ha (15 to 49 ha). It shows that the yields of all cereal crops on biodynamic farms for years 1979/1980 and 1980/1981 were lower by 13%, while the biodynamic and conventional farms had similar gross revenues per ha. The gross revenues from animal husbandry were 25 to 54% lower on the biodynamic farms (Koepf, 1986). However, because the biodynamic farmers had lower costs than the conventional farmers, their profits were higher. A similar study in Australia (Penfold, 1993) reports that conventional yields were highest (3.5 ton/ha) and biodynamic yields were lowest (2.3 ton/ha) in 1992. However, the biodynamic farms had the highest total gross margin per ha for the first four years (1989-1992), followed by the conventional, organic, and integrated treatments systems (Reganold, 1995). If the external costs are included in the costs of production, the profitability and benefits to society have been shown to be the greater for some alternative farming systems (Holmes, 1993). An analysis of the crop diversification experiences in the Asia-Pacific region covers 44 countries (Shome, 2009). Shome concludes that the advantages of crop diversification are connected with comparatively high net return from crops; higher net returns per unit of labor; optimization of resource use; higher land utilization efficiency and increased job opportunities. Recommendations include that governments should take steps to reduce risks and improve marketing facilities through improved roads and communications, construction of wholesale markets, access to credit (Shome, 2009).

Shiva (1992) states: "there is a general misconception that diversity based productive systems are low productivity systems." In reality, diverse systems, including permaculture, comprise a "symbiotic relationship between soil, water, farm animals and plants", which is rarely found in conventional agriculture.

The first peer-reviewed study directly comparing biodynamic and conventional farms was carried out in New Zealand on 16 farms (Reganold, Palmer, Lockhart, and MacGregor, 1993). It assessed the effects on soil quality and financial performance of biodynamic and conventional farms. The economic results of biodynamic farming practices for at least 8 years proved that biodynamic farms were financially as viable as their conventional counterparts.

Droogers and Bouma (1996) compare biodynamic and conventional soils on two neighboring farms, where each farming practice has been applied for at least 70 years. The biodynamic farming practices expressed higher yield potential, long-term stability and sustainability than conventional soils.

A long-term field experiment was installed in 1978 close to Basel comparing the "bio-Dynamic", "bio-Organic" and "(K)conventional" farming systems. Crop yields of the organic systems averaged over 21 experimental years at 80% of the conventional ones. The fertilizer input, however, was 34 – 51% lower, indicating an efficient production. Additional economic advantage was that the organic farming systems used 20 – 56% less energy to produce a crop unit and this difference per land area was 36 – 53% (Fließbach et al., 2004).

One deficit of diversified agroecosystems is that they can be profitable and with significant environmental benefits, but there is often absence of appreciation among farmers for system-level performance, i.e., performance of the individual components of a production system is valued more than overall system performance (Mulik, 2015).

Overall, it can be concluded, that there are mostly positive economic effects when practicing diversified agriculture (alternative, low-input, small-scale, permaculture or biodynamic) due to lower input-costs, higher net revenues and energy efficiency. Further macroeconomic positive effects can be specified for sustaining employment mostly due to labour intensive practices. Additional, and widely not measured potential advantage of agroecology systems versus conventional systems is that environmental externalities are not included in costs of the later. If such measurement was available, this would considerably contribute to both the economic benefits and climate changes effects of agroecology systems. A downside of this descriptive analysis is the limited comparison between the studies due to the differences in the applied methodology and different goals of each research report.

Identified research needs and pathways for mainstreaming agroecology

(1) The need of integration of science and traditional knowledge in engaging all the stakeholders towards a system-oriented thinking for sustainability of agricultural systems.

The example of mainstreaming organic farming should be taken in its positive aspects where it has been initially supported by individual researchers and later by large, government funded research programmes across the world. This seems to be the right step towards development of an “alternative” practice as agroecology and its main forms – permaculture and biodynamic agriculture. However, the developments that led to making large-scale organic farms to monocultures should also be assessed and avoided as much as possible in agroecology. Furthermore, challenges in front of Europe are connected with knowledge transfer to the farm community and to advisors and rural practitioners. Knowledge transfer between scientists, political decision-makers and the people directly affected by climate change is currently weak, and existing information is poorly used (Iglesias et al., 2012).

Major reforms must be made in policies, institutions, and research and development agendas to make sure that agroecological alternatives are massively adopted, made equitably and broadly accessible. It must be recognized that a major constraint to the spread of agroecology has been that powerful economic and institutional interests have backed research and development for the conventional agroindustrial approach, while research and development for agroecology and sustainable approaches has in most countries been largely ignored (Altieri et al., 2012).

(2) The importance of educating and training farmers in professional design and management of their agricultural holdings towards agroecosystems diversity.

Agroecological farming systems are very knowledge intensive, and require capacity-building and strong institutional support. These systems demonstrate the potential for sustainability of agricultural systems but also highlight the need for skills and dedication. Some successful approaches include farmer field schools and/or farmer-to-farmer training (Bogdanski, 2012).

(3) The access to professional advisory and extension services specifically experienced and trained in agroecology and agroecosystems diversity.

Extension may foster the culture of innovation, experimentation, and learning among farmers. This helps them to more rapidly form accurate judgements about innovations (Pannell, 1999). Studies from Nigeria show that education, extension, and crop diversification significantly decrease variance of technical inefficiency of the small-scale farmers (Ogundari, 2013).

(4) The access to funding for small-scale farmers.

Agricultural investments are needed specifically targeted to help small-scale producers to improve their farms’ and surrounding environmental through agroecological practices. Agroecological systems are complex and knowledge intensive and require a transition phase.

Small-scale farmers need to be supported and informed to enable them to accept risks associated with innovation and technical changes must reflect local resource needs and constraints. If agroecology is to coexist with conventional agriculture systems, then public funding for agroecological approaches need to match the funding for intensive agriculture.

(5) The support of local community organizations.

Strategies for development of organic farming in Turkey include more scholar research about its economic aspects; marketing research for establishing of local markets and marketing centers, establishing cooperatives; training programmes and education for producers and consumers; less dependency on import in the long-term; improvement of extension services, etc. (Kenanoglu, Karahan, 2002). Acting on a local level is in harmony with the permaculture concept focused on the economic development of local communities.

(6) The development of local and farmers' markets.

In many studies, the need for establishment and development of alternative markets is a necessity on the way of shifting towards diversification. Agroecosystems diversity systems are usually embedded in social, political and economic conditions that differ from those accompanying industrialized monocultures, particularly with respect to core stakeholder, markets and distribution systems (Kremen et al., 2012). The market failures of the conventional systems are paving way for agroecology, but still their environmental costs are paid for by the state and taxpayers. At the same time, the positive externalities of agroecology are not recognised in the prices farmers receive. Silici (2014) recommends re-orienting national and international trade policies by ending perverse subsidies in industrialised countries, and agree on and introduce valuation of externalities in national and international markets.

(7) The increase of trust between contracting parties (consumers, producers and intermediaries) for lowering of transaction costs.

Transaction costs are connected with market transactions. These are costs for an agreement or costs of various types in any negotiation like costs of time taken in the negotiations; psychological costs to the participants; social costs to the participants; possibly costs from legal action or mediation; and costs of monitoring and enforcing any agreements reached (Pannell, 1999). The social capital in extension groups helps to promote transfer of farmer skills and knowledge and may help to reduce transaction costs involved in negotiations. It is also connected to an increase in trust between the parties.

The social capital plays a key role in the production of human capital and public goods, good governance, financial development, political participation, efficiency of the judiciary system, political accountability, labor market institutions, etc.

Strengthening of producers' organizations, such as cooperatives, associations, boards of producers, networks, etc., has been promoted to counteract an unbalanced bargaining power in market transactions (Welsh, 1997; Paumgarten et al., 2012).

Conclusion

According to our findings, the adoption of the principles of diversification of crops, trees and animals increase the resilience of farms to climate change and environmental pressures on the one hand, and on the other, improves their economic results via low-input decisions and stability in yields. Man-made agricultural systems can resemble naturally diverse systems through appropriate design and management decisions and at the same time to provide economic and environmental efficiency like in permaculture designed farms, for example. At

the same time, promoting and mainstreaming agroecosystems diversity across farms and regions in Europe requires targeted and simultaneous actions at the local, national and European levels both in terms of institutional and policy support and development of markets.

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