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Organic Agriculture and Sustainable Food Production System: Main Potentials

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While organic agriculture (OA) is rapidly expanding, the important question is to understand how OA can contribute to sustainable food production system (SFPS). The SFPS is holistically defined by the American Public Health Association (APHA, 2007) as "one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment. A sustainable food system also encourages local production and distribution infrastructures and makes nutritious food available, accessible, and affordable to all". Prior to understand the main potentials of OA in approaching sustainable food system, it is important to note that neither other agricultural approaches; i.e. conventional (characterized by mechanization and the use of synthetic inputs such as chemical fertilizers and pesticides, with an emphasis on maximizing productivity and profitability) and biotechnological (characterized by a range of advanced tools employed to manipulate the genetic make-up of living organisms to make or modify agricultural products), nor OA can address all the aforementioned aspects of the SFPS. In fact, the aspects are complex and appear differently across countries and regions (Carvalho, 2006). One can distinguish bio-physical drivers such

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as soil degradation and water scarcity while others may more appreciate socio-economic and political drivers such as poverty (Azadi *et al*., 2011; Bazuin *et al*., in press; Middleton, 2008; Smith *et al.*, 2000); urban bias in policy making (Jenkins & Scanlan, 2001); rising food prices (USDA, 2007); and the lack of infrastructures (Middleton, 2008). It is also important to note that none of the aspects stand alone but are interrelated in many ways and may lie on different local and global levels.

When taking into consideration the aspects, especially when facing natural threats (e.g. acute and chronic droughts), in comparison to the other agricultural approaches, OA can make a significant contribution to SFPS as it can better deal with the negative impacts of climate change (Pimentel *et al*., 2005). It means that food production under organic management is more resistant to the threats; hence, the yield of crops is more stable. This is very important as sudden losses in the yield can considerably manipulate world food prices (Lobell *et al*., 2011) that might especially affect the poor and vulnerable people in developing countries.

Climatic resilience On the top of conceived advantages for OA, it contributes to climate change mitigation (Scialabba & Müller-Lindenlauf, 2010; Niggli *et al*., 2007; Borron, 2006; Hodge, 1993). In general, organic farming systems have a strong potential for building flexible food systems to face uncertainties through farm diversification and enhancing soil fertility (Pimentel *et al*., 2005; Scialabba & Müller-Lindenlauf, 2010). Furthermore, as reported by the FAO (2008) OA "assists farmers in adapting to climate change by establishing conditions that increase agro ecosystem resilience to stress. Increasing an agro ecosystem's adaptive capacity allows it to better withstand climate variability, including erratic rainfall and temperature variations and other unexpected events". Therefore, OA can promote sustainable food security. Niggli *et al*. (2008) point to the inclusion of indigenous knowledge in organic farming as an important way to adapt climate change: "This knowledge is important for manipulating complex agro-ecosystems, for breeding locally adjusted seeds and livestock, and for producing on-farm fertilizers (compost, manure, green manure) and inexpensive nature-derived pesticides. Such knowledge has also been described as a reservoir of adaptations". The inclusion of the indigenous knowledge is also something that Muller and Davis (2009) stress as an important characteristic of OA in adaptation and crop development concerning climate change. Finally, OA stimulates the use of local seeds (Kilcher, 2007) which are very often more adapted to local climate conditions (Borron, 2006) though the total mitigation benefits of OA are hard to measure, as the approach is highly dependent on local environmental conditions and management practices. However, "Should all agricultural systems be managed organically, the omission of mineral fertilizer production and application is estimated to reduce the agricultural GHG emissions by about 20% — 10% caused by reduced N2O emissions and about 10% by lower energy demand. These avoided emissions are supplemented by an emission compensation potential through carbon sequestration in croplands and grasslands of about 40–72% of the current annual agricultural GHG emissions" (Scialabba & Müller-Lindenlauf, 2010).

Soil degradation, drought resistance, and water efficiency The expansion of soil degradation is one of the most serious bio-physical problems at the time being and a serious threat for food production systems (Niggli *et al*., 2007), especially in developing countries. "Each year about 10 million hectares of crop land are lost due to soil erosion" (Pimentel, 2006). This reduces the available land for food production, especially in Sub-Saharan Africa and South Asia (Lal, 2009). The problem is more critical when we realize that "more than 99.7% of human food (calories) comes from the land while less than 0.3% comes from oceans and other aquatic ecosystems" (FAO, 1998 in Pimentel, 2006). Accordingly, some researchers point to soil fertility as the most important dilemma for overcoming the problem of food insecurity, especially in developing countries (Lal, 2009), most importantly in Africa

(Sanchez, 2002). Improving soil fertility is therefore greatly important. OA contributes positively to the process of encountering soil degradation as it improves soil fertility. The organic farming's techniques (such as balanced rotations, organic amendments and reduced tillage) give a better structure to soil and make it more fertile (Niggli *et al.*, 2007). The fertile soil causes higher soil aggregate stability (Maeder *et al.*, 2002) and this is partly caused by the fact that macro fauna such as worms and ants are not eliminated any longer by pesticides (Niggli *et al.*, 2007). These tiny animals play a crucial role in the production chain: they have positive influence on water infiltration, drainage and water-holding (Giller *et al.*, 2003). Therefore, a better retention of water and resistance to drought is conceived (Muller & Davis, 2009). Consequently, a dry period will cause less damage to these crops in OA compared with the other approaches. Research even suggests that water capture in the organic farming's plots is 100% more than conventional plots (Lotter *et al.*, 2003) and organic systems, under dry conditions, often have higher yields than the conventional (from 7 to 90%) (Ramesh *et al.*, 2005). This is very crucial when we know that only less than 1% of the world's freshwater is accessible for direct human uses (FBP, 2011) from which, huge contribution (70%) is used for irrigated agriculture globally (UNESCO, 2003). Given the higher soil organic matters generated by organic practices which retain water more and longer than the soil from conventional systems, organic farming not only less depends on freshwater for irrigation (Fan *et al.*, 2005) but also it can save lots of energy used for irrigation (Schnepf, 2004). The increased water efficiency, drought resilience, and energy saving by organic systems is especially beneficial for farmers in developing countries (Azadi and Ho, 2010). In these countries, the energy sector is not developed enough (Tharakan *et al.*, 2007) and achieving higher local yields especially in times of drought and a reduced dependency on unsustainable water sources for irrigation is a necessary step in alleviating rural poverty and approaching sustainable agricultural system (Ziesemer, 2007). Therefore, the SFPS will be reinforced by OA, especially compared with the conventional and biotechnological approaches which: often neglect indigenous knowledge (Niggli *et al*., 2008); are based mostly on monocultures (which stimulate soil degradation); are less resistant to drought (Ramesh *et al*., 2005); and use water less efficiently (Lotter *et al*., 2003). In general, as stated by the executive director of IFOAM Markus Arbenz: “Conventional practices deplete soils and thereby undermine long term food security…” (Engllish, 2010).

Pest resistance Pests in food production systems are a serious problem as the incidence of pests negatively affects the crops’ productivity. According to Oerke (2006), despite the use of pesticides, pests have still caused around 40% loss in the world potential food. Hence, a high susceptibility of crops to pests negatively affects the SFPS. The crops’ resistance to pests is generally greater in organic systems compared to the conventional (Birkhofer *et al*., 2008). Different explanations exist. First, a greater resistance to pests can be due to the increased soil quality and enhanced microbial biomass (Birkhofer *et al*., 2008). Second, growing relatively slowly raises some chemical defenses in plants to a level that prevents them against most diseases and pests. This is in contrast to the conventional and more specifically biotechnological approaches where plants are allowed to grow unusually fast using much chemical nutrients whereby the accumulation of defense compounds is reduced (FAO, 2007). Third, the crops’ resistance is also stimulated because of the enriched biodiversity by OA which also enhances the diversity of natural enemies (Meyling *et al*., 2010). This stands in contrast to conventional agriculture where extreme use of agrochemicals in combination with expanding monocultures has already intensified pest problems. Also, OA is associated with the increased species richness and abundance of predatory invertebrates and birds (Fuller *et al*., 2005; Hole *et al*., 2005). The beneficial influence of OA further accounts for invertebrate feeders (Smith *et al*., 2010), insect pollinated plants (Gabriel & Tscharntke, 2007), bee diversity, flower cover, and plant species richness (Rundlöf *et al*., 2010).

Food security OA could, in the long term, also be considered as an important contributor to food security, as it addresses several issues as follow:

1. the ever increasing population growth (80 million per year according to UNFPA, 2010), especially in developing countries, asks for more efficient use of resources and less dependent methods on non-renewable resources (Azadi *et al*., 2010);
2. the problem of land degradation is threatening food security and is expected to be worsened (Eswaran *et al*., 2001);
3. taking into account climate change that calls for more adaptation of agricultural systems to extreme weather in order to keep the crops' yield sustainable (Rosenzweig & Parry, 1994); and
4. pest management problems which threaten food security and are expected to be worsened as a result of climate change (Coakley *et al*., 1999).

Thereby, a shift to OA will be more and more essential in order to renew the resources (mainly water and soil) to secure food production in the future. In other words, compared to the other approaches, OA:

1. uses water more efficiently (Thierfelder & Wall, 2009; Giller *et al*., 2003; Lotter *et al*., 2003);
2. relies much less on fossil fuels (Scialabba & Müller-Lindenlauf, 2010);
3. prevents land degradation and even improves soil fertility (Niggli *et al*., 2007);
4. is more resistant to drought (Muller & Davis, 2009; Thierfelder & Wall, 2009; Lotter *et al*., 2003; Ramesh *et al*., 2005);

5. produces higher yields under dry conditions (Muller & Davis, 2009; Thierfelder & Wall, 2009; Lotter *et al*., 2003; Ramesh *et al*., 2005);
6. includes local knowledge/varieties (Willer & Yussefi, 2007; Muller & Davis, 2009); and
7. is more resistant to pests (Meyling *et al*., 2010; Birkhofer *et al*., 2008; FAO, 2007).

In conclusion, a long-term transition towards OA could be encouraged. However, as OA, at least in short-term, produces lower crop yields (Maeder *et al*., 2002), there are some kinds of tradeoffs between organic and the two other approaches with respect to sustainability (in terms of long term potentials to produce enough food) and productivity. This means that although OA in the short-term may produce fewer, in the long-term may produce higher yields (Badgly and Perfetto, 2007) because it can better address important threats of food security such as soil degradation, climate change and pest problems. Nevertheless, we cannot ignore one billion hungers (FAO/WFP, 2010) and 3.7 billion malnourished (WHO, 2005 in Pimentel, 2011) people worldwide. Therefore, given the low productivity of OA at the present time, we still need the conventional and safe biotechnological methods to feed the hunger bellies. Accordingly, the transition should be regarded as a gradual shift to be able to challenge with the dilemma of the hungers and the malnourished people.

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