Permaculture - a promising way of building our (agricultural) future?

It is becoming increasingly necessary to strengthen the ecological foundations of food security and agro-ecosystems through the systemic design of sustainable food production systems, thus sustainably using valuable natural resources, employing and feeding large populations, lowering largely external (chemical) inputs, and increasing climate change resilience at the same time.

Why is the issue important?

Early in the 21st century, modern agriculture is confronted with major challenges: since the middle of the 20th century, "conventional" or "industrial agriculture" has depended heavily on external inputs such as synthetic chemical fertilizers, herbicides and intensive use of machinery, all of which depend on cheap oil. Consequently, agriculture is threatening its very ecological foundation (UNEP 2012); it depletes its own resource base, as soil fertility is steadily declining; soil, water and air are being contaminated; water resources are being depleted; and biodiversity destroyed. Research shows that humanity is approaching the end of several non-renewable resources, all important for agriculture, through excessive use: peak[1] oil, peak water and peak phosphorus[2] (Brown 2011, Gleick and Palaniappan 2010, Gleick et al. 2009, Cordell et al. 2009, Vaccari 2009). "Current patterns of food consumption have contributed to making the world food system unsustainable" (UNEP 2012). In addition, climate change and the increase of extreme weather events will (and in some locations already do) lead to further pressure on land and people. "Addressing climate change and achieving sustainability in the global food system need to be recognised as dual imperatives. Nothing less is required than a redesign of the whole food system to bring sustainability to the fore" (Foresight 2011). At the same time, estimates state that an overall increase in agricultural

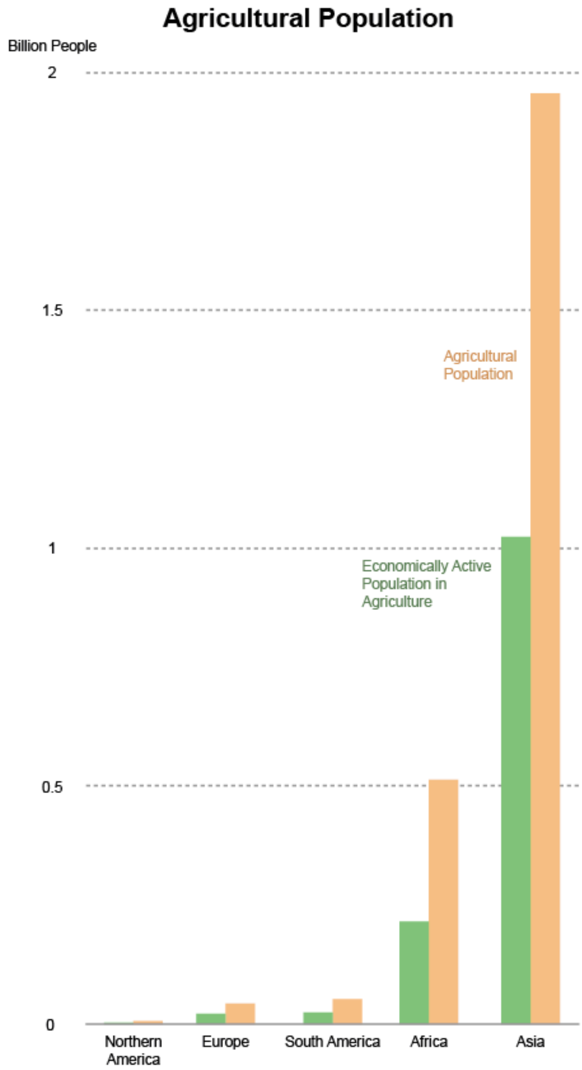

Figure 1: Agricultural population (including economically active population and their non-working dependents) and population working in agriculture. Source: FAOStat

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[1] Peak refers to the point in time when the maximum rate of a specific resource extraction (e.g. oil, water, phosphorus) is reached, after which the rate of production is expected to decline.

[2] Phosphorous is one of the most important plant nutrients and is being mined in large quantities in a few countries around the world.

production of 60% will be needed by 2050 (FAO 2012; cereals increase of 45%, meat production increase of 76%, oil products increase of 89%) in order to feed the anticipated 9 billion global population. Approximately 2.6 billion people, 40% of the world's population, depend on agriculture for their livelihood (Figure 1). Of the 525 million farms worldwide, 85% are smallholders who cultivate plots of land no bigger than two hectares (IAASTD 2009; Figure 2). Building sustainable world food systems may be necessary to secure livelihoods and the ecological foundation of food security.

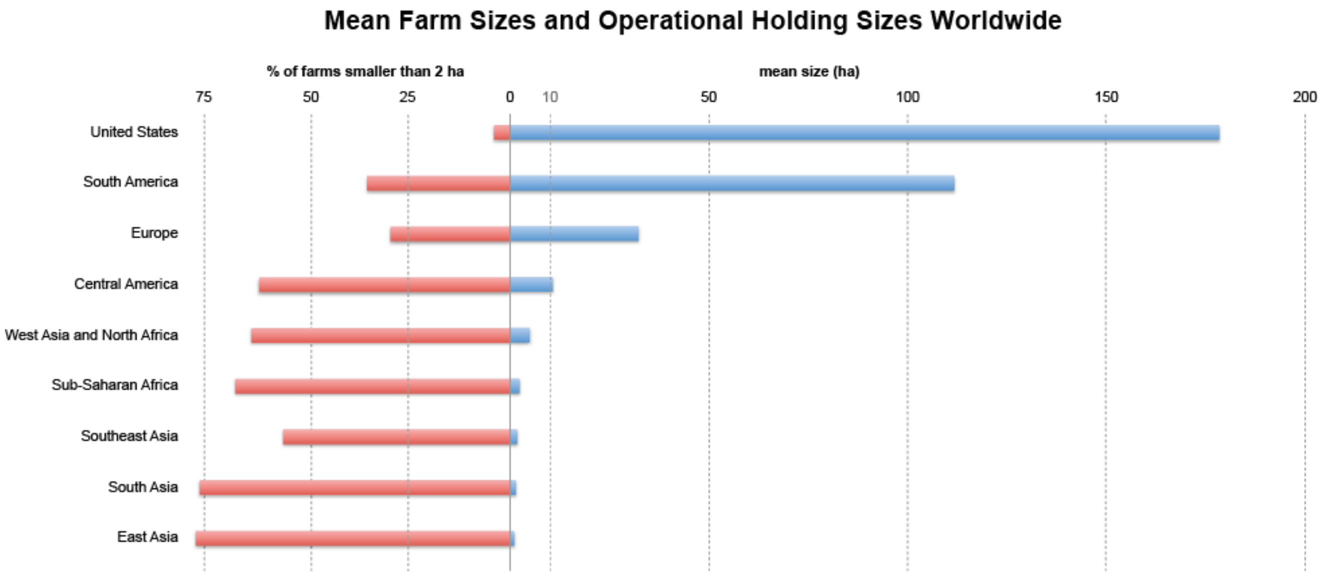

Figure 2: Mean farm sizes worldwide. Source: Eastwood 2010

Permaculture, in contrast to conventional agriculture, is a system which seeks to improve human ecologies (from farmlands to houses and cities) by mimicking nature (Altieri 2007), while at the same time eliminating largely external chemical inputs (petrol, fertilizers, herbicides) and improving soil quality and biodiversity (Holmgren 2002, Mollison 1988, Mollison and Holmgren 1979, Mollison and Holmgren 1978). Furthermore, by its very nature and scale, permaculture prefers use of local resources, has a long-term perspective in mind, connects land, people and economy, and thus favors smallholder development (not only in developing countries). As the Special Rapporteur on the Right to Food states: "Agriculture must develop in ways that increase the incomes of smallholders" (de Schutter 2010).

What are the findings?

The term permaculture is a contraction of the words "permanent" and "agriculture", where permanent has the meaning of durable, self-sustaining, or sustainable (Mollison 1988, Mollison and Holmgren 1979, Mollison and Holmgren 1978). It was coined by Australians Bill Mollison and David Holmgren in the 1970s, and developed in temperate island of Tasmania, Australia. Today, the permaculture concept is being used by many thousands of projects around the world, in all climates, vegetation and soil types, at both small and large scales (Mikhail 2012, De Schutter 2010, Bates and Hemenway 2010). Nowadays, it focuses not only on agriculture but also on a re-design of our culture towards sustainability.

Permaculture is both a philosophy and a toolbox, which helps (re)design human-made landscapes by looking at and imitating how nature acts. Underlying permaculture are three tenets (Mollison 1988):

- Earth Care - provision for all life systems to continue and multiply;
- People Care - provision for people to access those resources necessary to their existence; and
- Fair Share - by governing our own needs, we can set resources aside to further the above principles (some also describe the third ethic as “share the surplus”).

Permaculture helps to develop sustainable agriculture as well as human settlements through the establishment of self-sustaining systems modeled from natural ecosystems. By observing and understanding how nature works (a sustainable ‘system’ *par excellence*), we can try to mimic nature and use and combine existing resources (e.g. water, land, diversity, soil, slopes) intelligently and systemically. By working with and not against nature, we encourage the examination (and emulation) of well-functioning, self-sustaining and sustainable ecosystems. The nucleus of permaculture is to maximize beneficial connections between components; thus, the focus lies not on each separate element, but more importantly on the (positive) relationships that can be created among all of them by the way they are placed together.

There are two underlying principles in permaculture: First, every element (a plant, an animal, a construction, etc.) should fulfill multiple functions (a chicken lays eggs, eats slug eggs, provides feathers, produces heat which could be used in a greenhouse). Second, every function (pollination, fiber, food, etc.) should be fulfilled by several elements. The implementation of those two basic principles in a food-producing farm or landscape design creates a network of many relations between elements and functions that are “backed-up” through several elements. This creates a robust and resilient system.

Many disciplines - including organic farming, agroforestry, sustainable development, systems thinking and applied ecology - form the basis of permaculture. Permaculture also uses and integrates knowledge from traditional agriculture practices, but through the use of the above-mentioned systems, a distinct design process and the aim of developing self-sustaining systems, it goes much further. Implementation of permaculture principles is easiest at small scales, and is thus ideal for smallholders, but also offers great potential for large farms.

The following is a selection of methods, principles and approaches that can be seen as instruments out of a permaculture “tool box”:

Soil cover

One key observation is that in many natural ecosystems (besides areas with extreme climates), the soil is always covered with living or dead biomass: in the forest by leaf litter and creeping vegetation, in the savanna by grass. This element, it turns out, is of utmost importance for land productivity, as this forms and sustains humus-rich, living soil: without that soil, which includes animals, bacteria and fungi, the plants growing on that substrate will be neither healthy nor generate high yields. But the soil cover not only creates the natural, rich fertilizer that plants need for their growth; it protects the soil (and their life within) from the often harsh climatic conditions “above”. It is better protected against heavy rains, strong winds, high/low and rapidly changing temperatures, and thus reduces soil disturbance, erosion and degradation (UNEP 2012, Pretty et al. 2011, Mollison 1988). It also increases soil organic matter and leads to higher water holding capacity in the soil, raising nutrient levels and increased carbon sequestration (UNEP 2012, Bates and Hemenway 2010, IAASTD 2008). Several permaculture elements can be used to enhance soil fertility: no-tilling, perennial vegetation and mulching.

No-tilling

No-tilling in particular is receiving increasing attention worldwide (UNEP 2012, Friedrich et al. 2012, Derpsch et al. 2010, Godfray et al. 2010, IAASTD 2008). The soil is a living "organism" with its millions of creatures per cubic centimeter, from a myriad of different bacteria to the many fungi which decompose natural materials, to the earthworms which fulfill many functions such as aeration through the creation of their tunnels, the conversion of organic matter into rich humus, the creation of soil-organic complexes which improve the soil structure and the passages between upper humus-rich and lower humus-poor soils. In order to keep the soil alive, nutrient-accumulating and -conserving features in a healthy balance, any soil disturbance should be kept to a minimum, and the soil surface should always be covered with plant residues, which protect the soil and feed the soil organisms and living plants which can take up and store any nutrients that become available through decomposition (Bates and Hemenway 2010, Duiker and Myers, 2002). In some countries in Latin America, for example, over 70% of agricultural land has not been plowed for several years (Friedrich et al. 2012, Derpsch et al. 2010). Globally, in the last 11 years, the no-till agricultural surface grew by around 6 million hectares annually, especially in Latin America and Asia. Europe, however, seems to remain skeptical and growth rates are small, although interest is rapidly increasing, as a growing number of farmers proof its effectiveness (Friedrich et al. 2012, Derpsch et al. 2010).

Perennial plants

The use of perennial plants is another strategy to protect the soil surface (UNEP 2012, Glover et al. 2010, DeHaan 2007). Annual plants ("weeds") can usually thrive only on disturbed soils – such as tilled ones. This explains why farmers need to "fight" year after year against nature. If the environmental conditions permit, any disturbed land will evolve (in most climates) over time from a cover of annual weeds to a multi-year plant cover and then into shrub- and, much later, forest-like communities. By recognizing this natural force of succession, farmers could design a landscape that favors perennial over annual plants and yield many advantages.

Year-round coverage of the soil protects it from potentially negative natural forces, such as heavy rains, heat, strong sunlight and wind, all of which will degrade the soil in multiple ways. Furthermore, perennial plants develop a deep and thorough root system after a few years (Figure 3), which not only holds the soil together, aerates it better and helps to develop a better soil structure, but gives these plants a much higher tolerance during drier periods, as their roots can tap water

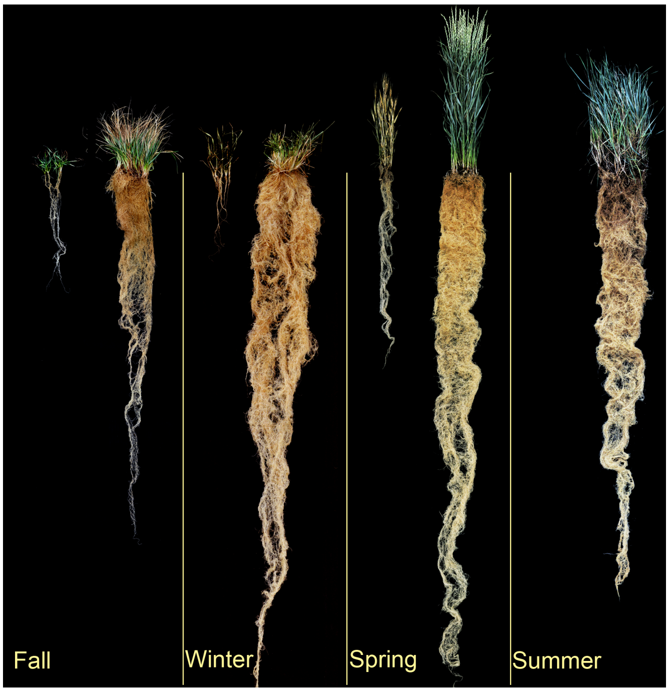

Figure 3: Annual wheat versus perennial intermediate wheatgrass. Seasonal development of annual winter wheat (left of each panel) and its wild perennial relative, intermediate wheatgrass (right of each panel). Source: Glover et al. 2010

from deeper soil horizons than annual plants. Compared with annuals, "perennial food plants provide more protection against soil erosion, manage water and nutrients more effectively, sequester more carbon, are more resilient to pests and stresses, and require less energy, labor and fertilizer" (Bates and Hemenway 2010).

Mulching

Mulching, i.e. the addition of (dead) biomass (and even stones in drier climates until sufficient biomass is available) onto the soil, joins the above-mentioned strategies for soil protection. It covers the soil in order to partially guard it from negative natural forces. But in addition it adds biomass, which can be converted by the soil organisms to organic material ("soil humus"), which improves many soil qualities mentioned above. It protects soils and plants' base and roots from large daily temperature differences, buffers cold night temperatures, suppresses weeds and offers a habitat for many insects and other life close to the soil.

Agroforestry

Agroforestry is the method of combining trees with crops (Figure 4). This brings the advantages of a forest – perennials, deep rooting system, protection against rain, wind and sun, production of nitrogen (one of the key nutrients for plants) through leguminous trees, habitat for wild species including crop pollinators - to an arable field. The advantages are numerous: they can provide farmers with food, timber, fuelwood, fodder and medicines, and they can enrich and stabilize the soil and improve the conservation of water (UNEP 2012, Dewees et al. 2011). It is especially beneficiary for the tropical and subtropical regions with high solar radiation, but is applicable in the form of alley cropping, for example, as well in moderate climates (UNEP 2012, Bates and Hemenway 2010, Tilman et al. 2002). Increases in yields of over 50%, in many places even over 100% and up to 300% (De Schutter 2010, Pretty et al. 2011) have been achieved. Nitrogen-fixing trees in particular, planted at densities of up to 200 trees per hectare, result in such steep increases in yields. Many international reports recommend the use of agroforestry for future agricultural production (UNEP 2012, Altieri 2012, De Schutter 2010, Godfray et al. 2010, World Agroforestry Centre 2009). In some regions such as Southeast Asia and in Central America, tree cover on agricultural lands now exceeds 30%. Furthermore, if best management practices were widely used, up to six gigatonnes of CO_2 equivalent could be sequestered each year using agro-forestry, which equals the current emissions from agriculture as a whole (Bates and Hemenway 2010, Trumper et al. 2009).

Figure 4: Agroforestry system, integrating poplar and wheat, Vézenobres, France. Credit: Vincent Chifflot

Polycultures

One of the main sources of today's problems in agriculture is the existence of pests which harm plants and can seriously reduce yields. This is driven mainly by low soil quality, which reduces the natural health of plants, and large-scale monocultures. These favor rapid development of "pest" insect populations. In a natural environment, such destructive forces are rarely present, as: a) heterogeneous ecosystems do not permit large increases of a single insect; and b) the natural enemy of these harmful insects is always present. If, under specific environmental conditions, a single insect can reproduce rapidly, the natural enemy will quickly do the same (as more of its food source is now available), thus countering an invasion or infestation.

"Several factors explain why sustainable agriculture has not yet become commonplace, such as lack of knowledge, lack of social support, socio-cultural constraints, lack of tailored equipment, lack of access to sufficient capital at the outset, a delay on return on investments, lack of tenure security, and non-conducive policy environments. Furthermore, the structure and incentives in existing agriculture and food supply chains do not enable a speedy transition to sustainable agricultural systems." (Foresight 2011)

The use of polycultures or multiple cropping systems – several plants grown together or within close distances - increases the number of potential feeding stations for beneficial insects, thus lowering greatly the threat of pests (Tilman et al. 2002, Mollison 1988). This also increases the general level of biodiversity, which is *per se* an important asset for our planet. As different cultures have different needs in terms of nutrients, and develop differently in regard to root structure (deep/shallow) and above-ground growth (low/high, thin/thick), fruit and vegetable plants can be grown together or in close proximity, and thus achieve mutually higher yields.

Water resources management

Agriculture consumes more than 70% of all freshwater withdrawals (Gleick et al. 2009, Postel et al. 2009). A growing percentage comes from non- or slowly-replenishable water sources, the use of which, by definition, is not sustainable. In the face of growing competition between multiple water uses, declining reservoirs and increasing pluvial uncertainties due to climate change, it makes good sense to boost farm efficiency. Conserving soil moisture through proper soil management (high amount of humus, year-round living or dead cover, shading), construction of terraces on slopes, microcatchments for all plants, small water reservoirs and swales are important tools (UNEP 2012, Milder et al. 2011, Godfray et al. 2010, IAASTD 2008) and lead, for example, to higher drought resilience (Hepperly 2003). Water recycling is important as well: a good example of the use of permaculture principles would be the collection of rainwater from rooftops, which can then be used for different purposes, for planting or showering for example. "Greywater" (e.g. water from showering or dishwashing) can be collected and used for toilets. Toilet feces and urine can be collected and used for composting and fertilization (not necessarily on vegetables, but under trees for example), which would mimic natural nutrient and resources cycles.

Figure 5: Biodiversity. Source: Stefan Schwarzer

Biological pest management

As described above, polycultures are an important asset in the prevention, or at least alleviation of crop diseases and pests (UNEP 2012). Integrated pest management "relies not only on biological control methods and ecosystem management, but also on better monitoring and understanding of pests" (UNEP 2012). It is being practiced widely in small- and large-scale farming systems throughout the world. So-called "push & pull" methods have been developed, where pests are "pushed" away from the main crop by inter-planting it with insect repellent crops (such as Desmodium), and being "pulled" towards small plots of other plants (like Napier grass) which attracts and traps pests (Khan 2011, Godfray et al. 2010). In Japan, "farmers found that ducks and fish were as effective as pesticide for controlling insects in rice paddies, while providing additional protein for their families" (Khan et al. 2005).

Integrated livestock management

Farmers have increasingly specialized in producing either crops or animals, mostly due to efficiency and profitability reasons. However, the combination of the two is often beneficial and farmers can take advantage of synergies between soil, plants, trees and animals (UNEP 2012, De Schutter 2010). Livestock would produce manure for enhancing soil fertility and the non-marketable biomass from crop production could be used to feed livestock. Hedges with their many advantages (as windbreaks, increase of biodiversity, yields of nuts and berries, wood for multiple purposes) could be used for feed as well. "Better integrated production systems would reduce livestock wastes and greenhouse gas emissions, and increase input and resource efficiency" (UNEP 2012).

Genetic resource management

In order to develop productive and sustaining agro-ecosystems, a greater diversity of species and varieties of crops, grasses, trees, soil organisms, and pollinators will be needed. They would more easily adapt to and absorb climatic variations and are more tolerant and resistant to pests and diseases (UNEP 2012, Jarvis et al. 2007, Foresight 2007). Over the last 50 years, "75% of the crop genetic base of agricultural crops has been lost" (IAASTD 2008), and only about 150 plant species are commercially cultivated worldwide today (Mikhail 2012) of which only 30 produce 95% of human calories and proteins; about half of our food comes from only four plants (Füleky 2009; Figure 6).

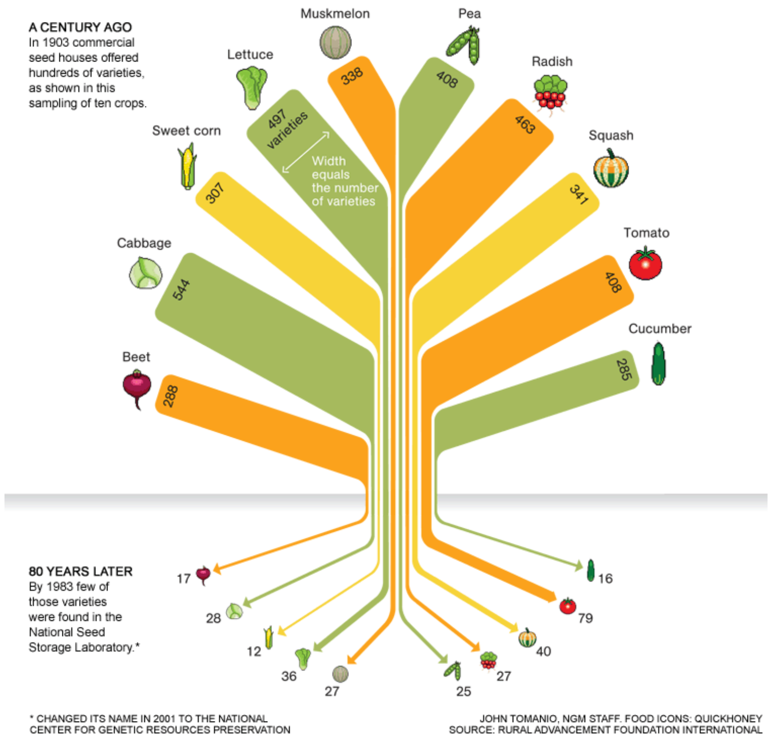

Figure 6: The declining diversity of agricultural varieties. Source: NGM.com using RAFI data.

Other

Although permaculture has its roots in agriculture, its principles[3] can be applied to other areas of our daily lives too, such as construction of buildings, energy production/consumption, social life and the economy. Here too, by using natural and/or recycled materials, by thinking about multiple functionalities, by including the "end of life" of a product into the design-phase, by using local,

[3] see for example http://permacultureprinciples.com/

bottom-up approaches, permaculture offers examples of its universal usefulness in order to develop truly sustainable natural and human ecosystems.

What are the implications for policy?

Permaculture is principally a design approach which derives its knowledge from (sustainably) functioning natural ecosystems in order to systemically and holistically (re)design human-made landscapes. This implies a paradigm shift in our thinking, returning from monolithic, linear, logical thinking to a connected, interwoven, complex system. "The ecological management of agro-ecosystems that addresses energy flows, nutrient cycling, population-regulating mechanisms and system resilience can lead to the redesign of agriculture at a landscape scale" (Pretty 2007). This is even more so the case as expected higher oil prices will bring current production methods, which are heavily based on petrochemical products, into question. The high rate of specialization of farmers and the market pressure (for cheap products) leaves farmers under current societal and economic conditions hardly any choice other than to grow and specialize even more. An alternative to industrial agriculture, at least in developed countries, looks increasingly essential in order both to diversify and move to a more integrated and sustainable form of food production (Beddington et al. 2012, OECD/FAO 2012, UNEP 2012, Foresight 2011, IAASTD 2008). Such an alternative form of food production needs to be supported on the one hand by governments (through changes in subsidies, for example), and on the other hand by citizens (through forms of "community-supported agriculture[4]" for example).

Generally, the two main production systems – industrial agriculture (especially in developed, but increasingly in developing countries too) and subsistence farming – both need a paradigm shift in order to sustainably produce healthy food within the laws of nature. In order to change the current situation and support the "adoption of sustainable agriculture practices around the world, policy makers can:

- Support farmers and community learning, for example, by educating a new generation of agricultural extension workers well-versed in the techniques of sustainable agriculture.
- Extend land tenure rights to farmers to encourage their stewardship of the landscape.
- Provide preferential access to credit for farmers willing to invest in more sustainable practices.
- Reward farmers and farming communities for ecosystem stewardship.
- Develop a "common vision" among stakeholders about how agriculture and food systems can be managed in a region.
- Strengthen national and international institutions, as well as private organizations, for the certification of sustainably grown farm products." (UNEP 2012).

More generally, it is important to train decision-makers at all levels in permaculture thinking and design, and therefore foster their competencies to choose techniques and tools appropriate for local conditions. In developed countries, it is important that people of all ages get in touch with nature (gardening for example) in order to (re)develop contact with the soil, plants, the seasons – which in turn can change household buying and consuming habits. A study in the United States (Alaimo et al. 2008) found that household participation in a community garden increased adult

[4] Community-supported agriculture (CSA) is an alternative, locally-based socio-economic model of agriculture and food distribution. Individuals may form networks or associations which pledge support for one or more local farms. Members may pay for a share of the anticipated harvest, in advance of the growing season, and receive shares of vegetables or fruit as they are harvested.

consumption of fruits and vegetables by a factor of 1.4, and households were 3.5 times more likely to consume fruits and vegetables at least five times daily.

In conclusion, international reports increasingly highlight the fact that agriculture is threatening its very ecological foundations, and there is thus a necessity to move towards a form of "sustainable agriculture" which can include elements such as agroforestry, agroecology, biological pest management, soil fertility and many others (Beddington et al. 2012, OECD/FAO 2012, UNEP 2012, Foresight 2011, UNEP 2009, IAASTD 2008). Permaculture can be seen as a tool that allows the intelligent use and combination of these, while taking into account local resources and constraints in the design and implementation of food production systems. While "permaculture" does not pretend to be a panacea to observed problems of food production and distribution, it may lead modern society to reconsider its agricultural practices, and perhaps offer an alternate, more environmentally-sound method to feed entire human communities and help them to live in closer harmony with nature.

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