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Agroforestry Can Enhance Food Security While Meeting Other Sustainable Development Goals

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Abstract

To achieve global food security, we need to approximately double food production over the coming decades. Conventional agriculture is the mainstream approach to achieving this target but has also caused extensive environmental and social harms. The consensus is that we now need an agriculture that can "multi-functionally" increase food production while simultaneously enhancing social and environmental goals, as committed to in the sustainable development goals (SDGs). Farming also needs to become more resilient to multiple insecurities including climate change, soil degradation, and market unpredictability, all of which reduce sustainability and are likely to exacerbate hunger. Here, we illustrate how agroforestry systems can increase yield while also advancing multiple SDGs, especially for the small developing-world agriculturalists central to the SDG framework. Agroforestry also increases resilience of crops and farm livelihoods, especially among the most vulnerable food producers. However, conventional yield-enhancement strategies have naturally dominated the debate on food production, hindering implementation of more multifunctional alternatives. Governments and institutions now have the opportunity to rebalance agricultural policy and investment toward such multigoal approaches. In doing so, they could achieve important improvements on multiple international commitments around the interlinked themes of food security, climate change, biodiversity conservation, and social well-being.

Keywords

food, security, agroforestry, development, sustainable

A major challenge to global food security is the need to approximately double food production over the next few decades, especially due to rapidly growing demand from the developing world (Food and Agriculture Organization of the United Nations [FAO], International Fund for Agricultural Development, & World Food Programme, 2015; Godfray et al., 2010; International Assessment of Agricultural Science & Technology for Development [IAASTD], 2009; The Government Office for Science, 2011; The Royal Society, 2009). To achieve yield increases, the use of chemical inputs, genetic improvement, and mechanization has now become conventional, thanks to their success in the past (with the important exception of Africa; IAASTD, 2009; Pretty & Bharucha, 2014; The Government Office for Science, 2011; The Royal Society, 2009). However, conventional agriculture has also been a principal cause of numerous social and environmental problems including climate change, loss of biodiversity and ecosystem integrity, land degradation, water insecurity, and disruption of social systems (Chappell & LaValle, 2009; Godfray et al., 2010;

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IAASTD, 2009; Maxwell, Fuller, Brooks, & Watson, 2016; Pretty & Bharucha, 2014; Pretty, Morison, & Hine, 2003; The Royal Society, 2009).

Consequently, there is now extensive consensus that we need to move away from the current, narrow focus on yield, and toward a more ‘‘multifunctional’’ agriculture that also respects (and preferably enhances) broader societal and environmental goals, under the rubric sustainable intensification (IAASTD, 2009; Godfray & Garnett, 2014; Pretty, 2008; Pretty & Bharucha, 2014; The Government Office for Science, 2011; The Royal Society, 2009). Indeed, the ongoing degradation of soils and ecosystems threaten the sustainability of food production itself, as does global environmental change (Amundson et al., 2015; Foley et al., 2011; Montgomery, 2007; Morton, 2007; Potts et al., 2010; Stern, 2007; Tan, Lal, & Wiebe, 2005; The Royal Society, 2009; Tscharntke et al., 2012). Here, we first suggest that the sustainable development goals (SDGs; Griggs et al., 2013; United Nations General Assembly, 2015) provide a broad and coherent framework for multifunctional agriculture, since this international agreement already combines food security (SDG2) with environmental, climate, and social goals and indeed emphasizes the need for a multigoal approach. We then describe how a highly multifunctional alternative already exists in agroforestry. We briefly explore how conventional agriculture tends to dominate in comparison to alternatives such as agroforestry, with multiple negative consequences. Finally, we outline considerations in creating a more appropriate balance of approaches.

One difficulty with a multigoal approach is that each agricultural option will affect each individual goal differently (and each actor will give different weight to the achievement of each goal). However, food is fundamental to human life, and so we assume that multigoal agriculture must first be able to increase yield sufficiently to meet the SDG of food security. Once that criterion is satisfied, the options that advance other SDGs most strongly (or compromise them least severely) would receive priority. In addition, each agricultural approach will affect the SDGs differently for different social groups and different geographies. Since food security and the SDGs in general are particularly relevant to the developing world (United Nations General Assembly, 2015), we focus our discussion on the small-scale agriculturalists who represent over 90% of developing-world farmers (Graeub et al., 2016; International Fund for Agricultural Development/United Nations Environment Programme [IFAD/UNEP], 2013) and also the majority of those living in poverty (World Bank, 2015).

Within that physical and human geography, one of the most multifunctional forms of agriculture is agroforestry: the combined production of trees and agricultural species on the same piece of land (see top photo in Figure 1; Garrity et al., 2010; Nair, 1993; Pretty & Bharucha, 2014). Although it has often been studied for its ecological benefits and peasant-farmer associations (Bhagwat, Willis, Birks, & Whittaker, 2008; Horlings & Marsden, 2011; Pretty et al., 2003; Shibu, 2009), scientific evidence now shows that the adoption of agroforestry can increase yields by a factor of two (average 96% in a multistudy review; Pretty & Bharucha, 2014), depending on crop type, local conditions, and level of expertise (Garrity et al., 2010; Pretty & Bharucha, 2014; Pretty et al., 2003; Waldron, Justicia, & Smith, 2015). These yield increases have been shown to reflect multiple ecosystem services provided by the trees, including enhanced soil nutrient status (e.g., through nitrogen fixation), reduced crop stress (e.g., through reduced temperature and rainfall extremes), reduced soil erosion (binding of soil by roots), and regulation of water supply (hydraulic uplift of deep water by tree roots; Garrity et al., 2010; Leakey, 2014; Pretty et al., 2003; Waldron et al., 2015). Furthermore, the yield improvements can be highly sustainable (secure) because agroforestry maintains soil fertility and can even restore degraded lands (Garrity et al., 2010; Leakey, 2014; Nair, 1993).

However, food security itself (SDG2) does not just depend on yield (FAO, 2008; World Bank, 2015). A further critical component is resilience to climate change and to shocks (sudden, large variations in weather, harvests, market prices, and input costs), which can cause major hunger crises (Chappell et al., 2013; Chuku & Okoye, 2009; FAO, 2008; Garrity et al., 2010; McMichael, 2009; Orr & Mwale, 2016; Thorlakson & Neufeldt, 2012; World Bank, 2015). Agroforestry increases crop resilience to several likely climate change effects, such as drought or higher temperatures, because it enhances water infiltration and storage while reducing evaporation and temperature extremes (Charles, Munishi, & Nzunda, 2013; Garrity et al., 2010). It also increases livelihood resilience because the provision of free ecosystem services by the trees reduces dependence on unpredictable, distant commodity markets; when harvests are poor, the trees also provide alternative sources of both income and food, for example, fruit, fodder, or fuel (Charles et al., 2013; Garrity et al., 2010; Thorlakson & Neufeldt, 2012).

In addition to advancing food security, agroforestry can also enhance multiple social dimensions of the SDGs. It provides a pathway out of poverty (a major driver of hunger itself; World Bank, 2015) because the combination of increased yield, low cost, and additional tree-based farm products can significantly increase net farm income (Miller, Munoz-Mora, & Christiaensen, 2017; Reyes, Quiroz, & Msikula, 2005; Waldron, Justicia, Smith, & Sanchez, 2012). In addition, farmer movements in the developing world have expressed a lack of equity and dignity (SDGs 10, 8, and 16) in the way their livelihoods can be negatively affected by distant supply-chain actors, and so have sought greater local

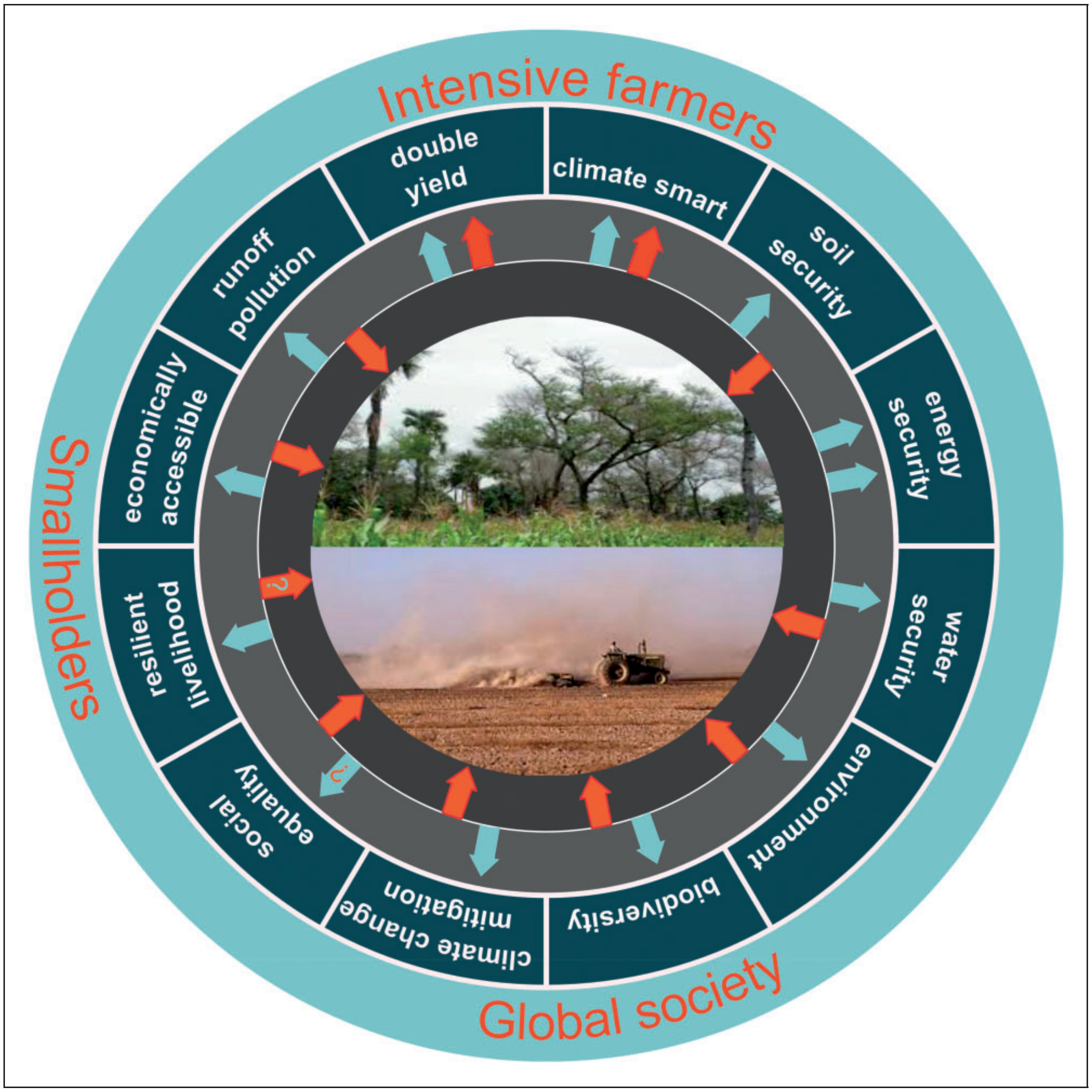

Figure 1. Agroforestry (top photo), conventional agriculture (bottom photo), and the achievement of multiple goals. Twelve goals are shown, all related to food security (especially for developing-world agriculturalists) and to other sustainable development goals connected with agriculture. Arrows compare how agroforestry (lighter blue) and conventional intensification (darker red) affect each goal: Arrows pointing away from the circle center indicate a likely positive impact on the goal, vice versa for arrows toward the center. To reflect uncertainties, arrow heights are arbitrarily equal? = Alternative theories exist for some goals, for example, social equality and livelihood resilience. Some goals are also important to global society (e.g., climate change and biodiversity) and larger farmers using conventional intensification (e.g., yield and climate-smart crops).

control of food production (e.g., "food sovereignty"; Chappell et al., 2013; Desmarais, 2007; Whitmann, 2011), see also (Cook, Silici, Adolph, & Walker, 2015; Thorlakson & Neufeldt, 2012). In agroforests, the reduced dependence on external chemical inputs, plus the greater resilience to market fluctuations, can enhance this sense of control, equity, and dignity in work (Chappell et al., 2013; Thorlakson & Neufeldt, 2012). Furthermore, on-farm trees generate considerable fuel-wood, reducing the need to cut down natural forests and also saving smallholder family members (particularly women) from walking long distances (sometimes >20 km) in search of firewood, thus enhancing women's well-being and freeing them to educate and tend to children, provide farm labor, or produce other income (e.g., SDGs 3, 4, and 5; Kiptot, Franzel, & Degrande, 2014; Sharma et al., 2016; Thorlakson & Neufeldt, 2012). The on-farm supply of fuel-wood also represents an important, hunger-related form of energy security (SDG7) for rural communities, being cheap, readily available, and fundamental to extracting sufficient calories from food (Sharma et al., 2016).

Agroforestry can also enhance several key environment-related SDGs. In addition to taking pressure off wood collection from natural forests (Sekhar, 2007), agroforests enhance biodiversity and ecosystem services (SDG15) by improving on-farm habitats and increasing landscape connectivity (Bhagwat et al., 2008; Clough et al., 2011; Schroth, Fonseca, & Harvey, 2004; Tscharntke et al., 2011). Agroforestry farms also make major contributions toward the mitigation of climate change (SDG13), for example, by adding 200 million tonnes of carbon annually to agricultural lands (Zomer et al., 2016). This figure does not account for any emission savings due to reduced off-farm tree felling and could be much higher if agroforestry were more widely implemented (Garrity et al., 2010; Minang, Duguma, Bernard, Mertz, & van Noordwijk, 2014; Shibu, 2009; Zomer et al., 2016).

In summary, agroforestry can offer a high-yielding system with multiple other SDG benefits. Many farms globally already have some trees (e.g., 46% of all farmland already has >10% tree cover; Zomer et al., 2016), and there is increasing realization (and take-up) of the benefits of introducing trees to low-yielding land (Garrity et al., 2010). Agroforestry techniques are therefore likely to be widely suitable across a large proportion of global farmland. There will of course be places where agroforestry cannot easily or efficiently be implemented, for example, where both the physical and cultural ground is not propitious to the introduction of new trees. Nevertheless, the same is true of conventional agriculture. For example, the high yields achieved by conventional Western agriculture require farmers to purchase a steady supply of inputs, which are accessible and subsidized in developed countries but often unaffordable for smallholders in more remote areas (IFAD/UNEP, 2013).

The key point is that, ideally, each agricultural approach should be implemented where it is most appropriate in a multigoal framework. This does not currently occur. Instead, many studies have shown how conventional approaches still dominate (including in the aid finance allocated to different food security options; Pingali, Spielman, & Zaidi, 2016), whereas agroforestry and similar nonmainstream approaches are underimplemented (Franzel, Denning, Lillesø, & Mercado, 2004; Horlings & Marsden, 2011; International Panel of Experts on Sustainable Food Systems, 2016; Pretty et al., 2003). Indeed, discussions of sustainable intensification itself have often focused on conventional yield enhancement (Cook et al., 2015; Horlings & Marsden, 2011; IAASTD, 2009; The Royal Society, 2009). More worryingly, conventional approaches to intensification continue to cause the removal of trees from existing agroforestry systems (Siebert, 2002; Waldron et al., 2015), just as tree cover has been lost from nonagroforestry agriculture (Fischer, Zerger, Gibbons, Stott, & Law, 2010).

The predominance of mainstream, conventional agriculture is unsurprising. Farming choices do not exist in isolation but depend upon an entire "food regime" of agribusiness, inputs, subsidies, markets, research and regulation, in which smallholders tend to have minimal influence, control, or lobbying power (McMichael, 2009). A whole set of institutions, regulations, and subsidies have been shaped around the conventional approach, making the implementation of alternatives such as agroforestry more difficult (Franzel et al., 2004; McMichael, 2009). Where political and financial interests exist, current power structures will also tend to resist change. However, if multiple agricultural options can deliver food security to a region, it makes little policy sense to choose those that will compromise soils, biodiversity and ecosystem services, climate, and even social capital more severely.

We suggest a target of "high enough yield for food security, with maximal co-benefits," particularly in the developing world. We recognize that achieving maximum yield (rather than achieving sufficient yield to meet demand) has often been an economic goal, and that conventional agriculture may often be a stronger candidate for achieving this. However, whether we aim for sufficient or maximal yield, it is critical that any calculation of multigoal trade-offs considers historical context and potential, rather than being limited to a snapshot of the present day. Conventional agriculture was not always so productive, but became so due to half a century of intensive investment and research (Pardey, Beintema, Dehmer, & Wood, 2006; Pretty & Bharucha, 2014), and its incremental yield gains have slowed compared with earlier stages of development (IAASTD, 2009; The Royal Society, 2009). In addition, billions of additional dollars are now spent trying to improve conventional agriculture's poor environmental performance, with limited success (Kleijn et al., 2006; Monke & Johnson, 2010). In comparison, investment in agroecological systems has been an order of magnitude smaller (DeLonge, Miles, & Carlisle, 2016). The implication is that if greater investment were made in less-developed approaches such as agroforestry, yield could increase substantially, greatly reducing or even reversing any current yield gap with conventional agriculture and thus changing trade-off calculations.

In conclusion, we now have the opportunity to refocus both policy and finance, so that they better reflect an appropriate balance of agricultural solutions in a multigoal framework. For less-mainstream techniques such as agroforestry, such a rebalancing would bring large new investment, research, and institutional improvements, driving yields upwards. By assessing and capitalizing on this potential, we could significantly enhance global goals on food security, social well-being, and environmental integrity, as we have committed to under the SDGs.

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