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Agrochemical Management Combating the Challenges of Organic Farming

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Abstract

Agrochemicals play a key role in increasing agricultural productivity by protecting crops from insects, pests, fungi, weed, rodents etc. Owing to their benefits, they have been used indiscriminately rising concerns over their usage. Nevertheless, they are indispensable in agriculture to maintain productivity as the population is exponentially increasing and so is the demand for food. Hence there is a need to employ a policy for the management of the agrochemicals to encourage their judicious use.

Keywords :-organic food, nutrition and health effects, environmental effects, climate change, technology adoption, smallholder farmers

Benefits of Pesticide Use:

Plant insects and pest incur a major loss to farmers worldwide every year. It has been estimated that insects destroy 15% of crops, disease pathogens and weeds around 13% each and pests during postharvest period damage 10% of crops. Agrochemicals help minimize this loss by protecting crops, increasing productivity and maintaining the quality of the produce. This also saves other costs such as labour and fuel which in turn lowers the prices of agricultural commodities.Apart from their use in agriculture, agrochemicals are also used to prevent negative impacts caused to society in many ways. For example, trees and weeds growing under power lines, when left unchecked, would result in power outages. Herbicides are used to eliminate this growth. Also, herbicides are widely used to control unwanted vegetation along national highways, roadsides, in parks, wetlands and public areas to ensure public safety and convenience.In food processing, insecticides are used in permissible levels to protect raw commodities and packaged groceries from insects infesting them during processing, manufacturing and packaging stages. Insecticides and rodenticides are widely used in places where food is stored. Insecticides, herbicides and pesticides are also used in the home for controlling insects, herbs and pests.

CAN ORGANIC AGRICULTURE FEED THE WORLD?

Many see organic agriculture as the most sustainable form of farming and as the paradigm for global food production in the future. Hence, the question of whether organic agriculture alone could actually feed the world with its 7.5 billion people today, and likely over 9 billion people by 2050, arises time and again (Badgley et al. 2007, Connor 2008, Erb et al. 2016, Seufert & Ramankutty 2017, Muller et al. 2017, Taheri et al. 2017). Given that organic farming today only accounts for 1% of the agricultural land, a total conversion to organic agriculture does not seem to be a realistic scenario in the foreseeable future, but it is nevertheless an interesting thought experiment.

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Food Production Quantities

As discussed, average crop yields are lower in organic than in conventional agriculture. Consequently, total conversion to organic practices would require more land to produce the same quantity of food. Section 3 discussed the average organic yield gaps of 19–25%, which would mean additional land requirements of 23–33%. But in Section 3 we also discussed that yield gaps could increase if more farmers adopted organic agriculture. Organic farming is more knowledge intensive than conventional farming; therefore, there is little reason to assume that organic yields obtained on experimental stations or on 1% of the agricultural area could be extrapolated to all agricultural land worldwide. Larger yield gaps are especially likely when it comes to upscaling organic agriculture in the developing-country small farm sector, where levels of formal education are often low, and access to agricultural training is limited. Average yield gaps of 30–40% would already mean that 43–67% of additional land would be required to produce the same quantity of food with organic practices, implying a significant loss of natural habitats.

Another relevant question is whether sufficient nutrients from organic matter would be available if all of the world's agriculture were converted to organic practices (Tomich et al. 2011). Today, organic agriculture often relies on nutrient inputs from conventional farms and heavily depends on the livestock sector (Nowak et al. 2013). But would there be enough animal manure available to supply nutrients to a much larger area under organic production? Currently only about 11% of the nitrogen inputs to global crop production come from animal manure, and another 8% are from crop residues (Seufert & Ramankutty 2017). Completely replacing synthetic fertilizers, which are banned in organic farming, would mean significantly increasing the number of farm animals kept. Given the climate effects of animal husbandry and the additional land required for fodder production, this would hardly be a sustainable scenario. Alternatively, more leguminous cover crops could be grown to restore nitrogen in the soil. However, providing sufficient nitrogen would require a legume cover crop on each field every year, which would not be possible without reducing the area available for food production (Connor 2008). Providing insufficient nutrients would mean additional yield gaps.

In summary, providing sufficient food for the growing world population through organic farming alone might be possible but not without taking significantly more land into production. The expansion of agricultural land is a major contributor to biodiversity loss and climate change (Foley et al. 2011, Green et al. 2005). As discussed in Section 5, the biodiversity gains from organic production cannot offset the biodiversity losses associated with additional land-use change. In other words, complete conversion to organic agriculture would likely be associated with additional GHG emissions and a net loss in biodiversity.

Sustainable Consumption

When calculating the food quantities that have to be produced to feed the world population, current patterns and trends of food consumption are typically assumed. However, a significant share of the food produced is lost or wasted along the value chain, including foods thrown away by the end-consumer (FAO 2011). Moreover, the high consumption of meat and dairy products in many parts of the world is associated with considerable resource inefficiencies. In other words, much less food production would be required if food losses and waste were reduced and if all people became vegetarians or vegans. Such a scenario could certainly change the conclusions about the potential of organic agriculture to feed the

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world. Indeed, in recent simulations, Erb et al. (2016) and Muller et al. (2017) showed that the predicted world population in 2050 could be fed even with lower yields and without the loss of additional natural habitat if only vegan diets were consumed.

However, completely vegetarian or vegan diets are not realistic and also not desirable from a nutritional perspective (Seves et al. 2017, White & Hall 2017). Nor do vegetarian or vegan diets fit together with increased organic production, as organic practices depend on the availability of animal manure. But with or without organic agriculture, changes in people's consumption habits toward less resource-intensive diets will have to be an important part of sustainable development strategies (Foley et al. 2011). Especially in rich countries, this should also involve less consumption of animal products. In several countries in Europe, the per capita consumption of meat is actually decreasing, but the decrease is slow. Behavioral change processes are not easy to instigate and accelerate through political measures, and the global trend goes in the opposite direction. Especially in Asia and Africa, the demand for animal products is rapidly rising, and the situation is similar in terms of food losses and waste. Although reductions are desirable, a zero waste scenario is hardly realistic in the foreseeable future.

Food Prices and Food Security

Mainly owing to lower average yields, organic production is associated with higher costs per unit of output and thus higher prices (see Section 2). Currently, the higher prices only apply to the small certified organic market segment, but total conversion to organic agriculture would mean significantly higher food prices in the entire market. In developed countries, most consumers are sufficiently rich so that higher food prices would not jeopardize their food security. But in developing countries, the situation is different. Many poor households spend over 50% of their income on food. In such situations, food price increases are associated with higher levels of food insecurity and undernutrition, especially in urban areas (Ecker & Qaim 2011). For farming households, higher agricultural prices are welcome as such, but when higher prices are the result of lower yields, they do not necessarily lead to higher incomes. The socioeconomic effects of organic agriculture for farming households are analyzed in the following section.

SOCIOECONOMIC IMPLICATIONS FOR ORGANIC FARMERS

Organic farming can only contribute to sustainable agricultural development when it is economically viable for farmers, meaning that the income derived from organic production is at least as high as that from conventional farming. A recent meta-analysis has analyzed this issue and includes studies from 14 different countries (Crowder & Reganold 2015). Results show that organic farming is 22–35% more profitable than conventional agriculture on average. While organic yields are significantly lower, organic farmers receive higher prices for their products in certified organic markets. Average price premiums at the farm level are on the magnitude of 30%. Without price premiums, organic farming would be less profitable than conventional farming (Crowder & Reganold 2015).

Whereas the meta-analysis by Crowder & Reganold (2015) includes data from different parts of the world, most of the original studies refer to the United States and other developed countries. Only a few of the studies refer to developing countries, and no single study looked

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at the situation in Africa. In terms of absolute numbers, most organic producers are smallholder farmers in developing countries. Moreover, smallholder farmers comprise a large share of the world's poor and hungry people (FAO 2014, Qaim 2017). Hence, a better understanding of what organic farming can mean economically for farmers in developing countries is important (Jouzi et al. 2017). A review of studies focusing on socioeconomic aspects or organic farming in Africa, Asia, and Latin America is provided below.

Smallholder Farmers and Organic Yields

As discussed in Section 3, yields obtained with organic production methods tend to be lower than those in conventional agriculture. However, yield differences depend on the particular context. In situations where most farmers have limited access to modern production technologies and apply low quantities of purchased inputs anyway, organic yields can be similar to conventional ones (Beuchelt & Zeller 2011, Jena et al. 2017, Kramol et al. 2013, Parvathi & Waibel 2016). This is not an untypical situation of smallholders in developing countries, especially in Africa. With intensive training and a substantial increase in the use of organic fertilizers, organic yields can even be significantly higher than those obtained from low-input conventional farming (Bolwig et al. 2009, Ibanez & Blackman 2016, Wollni & Andersson 2014). Employing organic soil management practices can also reduce yield variability and vulnerability to drought and other weather extremes (Niggli 2015, Scialabba & Müller-Lindenlauf 2010). However, where modern inputs are available and more commonly used, organic farmers typically have lower yields than conventional farmers. Yield gaps tend to increase during the process of economic development (Valkila 2009).

Price Premiums

Most organic farmers in developing countries produce cash crops (e.g., coffee, tea, cocoa, tropical fruits) for export to rich countries, where consumers pay a significant price premium for certified organic products (Raynolds 2004, Willer & Lernoud 2017). However, the price premium at the retail level is not necessarily reflected in the price that farmers receive for their organic produce because various actors along the value chain also capture some of the benefits (Minten et al. 2018). In some cases, prices received by organic farmers in developing countries are not higher than those in conventional markets (Chiputwa et al. 2015, Parvathi & Waibel 2016). Nevertheless, most studies find that organic premiums at the farmer level range between 6% and 44% (Beuchelt & Zeller 2011, Bolwig et al. 2009, Ibanez & Blackman 2016, Jena et al. 2017, Jones & Gibbon 2011, Kleemann et al. 2014, Mitiku et al. 2017, Valkila 2009).

However, oftentimes organic smallholders do not sell all of their harvest in certified markets (Jena et al. 2012, 2017; Kleemann et al. 2014). There are several reasons why they may decide to sell some or all of their crops in conventional markets. First, sometimes the quality requirements of certified markets cannot be met (Bolwig et al. 2009, Weber 2011). Second, there can be situations when the farmer organizations lack the capacity to handle the large supply of certified crops delivered by their members (Jena et al. 2012, Snider et al. 2017). Third, price premiums vary and can be small during certain periods (Snider et al. 2017). Finally, even when price premiums are more significant, selling in certified markets is often associated with payment delays. When facing urgent cash needs, organic farmers sell to local traders at lower prices but in return for immediate cash (Bacon 2005, Beuchelt & Zeller 2011, Valkila 2009). Given these conditions and constraints, the average price that organic smallholders receive may be lower than what the reported price premiums may suggest.

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Production Costs

In the small farm sector, certification fees and related administrative costs are typically covered by farmer cooperatives, exporters, or development organizations. However, meeting certification requirements is often associated with certain investment costs (e.g., new equipment) that farmers have to bear individually (Kleemann et al. 2014). Also, organic certification involves a three-year transition period, which can be understood as a sunk cost. During this transition period, farmers cannot yet benefit from an organic price premium, but yields are often particularly low due to learning and experimentation with the new production methods (Caldwell et al. 2014, Ruben & Fort 2012, Weber 2011).

Organic certification can also influence variable production costs. Although costs for chemical inputs are saved, maintaining and increasing yields requires large quantities of organic material (e.g., manure). The organic matter available at the farm itself may not suffice, so that additional material has to be purchased (de Ponti et al. 2012). The cost can be substantial, especially when local market supply of organic matter is limited (Jena et al. 2017, Kloos & Renaud 2014). Furthermore, organic farming is typically more labor intensive, as manual labor is needed for weeding, application of organic fertilizers, and other operations (Valkila 2009). Consequently, households have to hire additional labor or use more family labor (Beuchelt & Zeller 2011, Kleemann et al. 2014, Ruben & Fort 2012). Most studies focusing on developing countries do not account for the opportunity cost of family labor. With the increasing availability of off-farm income opportunities, this may lead to underestimation of the total production costs in organic farming.

Indirect Economic Benefits

In addition to possible price premiums, organic certification may also be associated with indirect economic benefits. In developing countries, certified farmer organizations (or buyers) usually offer services, such as price information, training, credit, or value addition, to help farmers meet certification requirements and produce the quality demanded in international organic markets (Bolwig et al. 2009, Jones & Gibbon 2011). As smallholder access to rural services is generally low, such initiatives by certified organizations can improve the situation more broadly and result in income gains (Mitiku et al. 2017, Parvathi & Waibel 2016). However, the range and quality of services to be provided is not specified in organic standards, so the relevance of such indirect benefits varies (Jena et al. 2012, Meemken et al. 2017a).

Collective marketing or contractual arrangements are also commonplace in smallholder organic value chains. Such arrangements can be beneficial for farmers irrespective of organic certification (Bellemare 2012, Fischer & Qaim 2012). But as new marketing institutions are often established as part of certification initiatives, related gains for individual farmers can also be considered as indirect benefits of participating in organic agriculture.

Overall Profitability and Income

The previous subsections showed that yields, prices, and production costs in organic farming are highly context specific. As a result, studies come to different conclusions regarding the overall profitability of organic certification. Some studies find that the price premium is insufficient to compensate for lower yields and/or higher production costs (Barham & Weber 2012, Ibanez & Blackman 2016, Mitiku et al. 2017). Other studies suggest that organic

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certification contributes to higher profitability in the small farm sector (Bolwig et al. 2009, Kleemann & Abdulai 2013, Kleemann et al. 2014). We conclude that the profit effects of organic farming are less clear cut in developing countries than what the global meta-analysis of Crowder & Reganold (2015) suggests.

However, a narrow focus on the profits from one certified crop alone may yield an incomplete picture of the overall economic impacts of organic farming. This is especially true in the small farm sector, where households usually engage in multiple farm and off-farm activities. For instance, when households decide to allocate land, labor, and capital to organic production, the income from other economic activities may also be affected through resource reallocation and other types of spillovers. Several studies have analyzed the effects of organic certification on total household income, thus implicitly capturing spillovers. Again, the results are mixed and context specific. While some studies suggest that organic certification has no effect or even negative effects on income and the likelihood to be poor (Barham & Weber 2012, Beuchelt & Zeller 2011, Chiputwa et al. 2015, Jena et al. 2017, Mitiku et al. 2017, Valkila 2009), others find exactly the opposite (Ayuya et al. 2015, Jones & Gibbon 2011, Kleemann & Abdulai 2013).

Broader Social Development Goals

Unlike other sustainability standards, such as Fairtrade, most organic standards do not include specific certification requirements related to social issues, such as child labor or gender equality (Meemken & Qaim 2018, Seufert et al. 2017). Nevertheless, studies suggest that organic certification can affect social outcomes in positive and negative ways. If it improves income, organic certification may enable households to make beneficial investments in human capital formation. For instance, Gitter et al. (2012) show that double organic-Fairtrade certification has a positive effect on child education in Mexico. Such investments in better child education are unlikely to occur in the absence of income gains, as Meemken et al. (2017a) show with data from organic coffee producers in Uganda.

Several studies have also analyzed nutrition effects, suggesting that organic certification helps to improve food security and dietary quality in farming households (Becchetti et al. 2012, Chiputwa & Qaim 2016, Meemken et al. 2017a). Positive effects on dietary diversity can even occur in the absence of income gains (Meemken et al. 2017a). One reason is greater production diversity on organic farms, which is known to affect household dietary diversity through the subsistence pathway (Sibhatu et al. 2015).

Organic farming can also reduce occupational health hazards, as farmers and farm workers are less exposed to chemical pesticides (Asfaw et al. 2010, Forman & Silverstein 2012, Shreck et al. 2006). The ban of chemical pesticides can also have interesting gender implications. On the one hand, pesticide bans can increase women's workload, as women are often heavily involved in labor-intensive activities such as weeding (Bolwig 2012, Lyon et al. 2010). On the other hand, pesticide-free production can promote women's participation in cash cropping (Kloos & Renaud 2014). The reason is that the handling of pesticides is primarily considered a male task in many parts of Africa and Asia. More generally, organic certification can have effects on labor markets and employment conditions in the farming sector and also further downstream (Taheri et al. 2017). Such effects are not yet sufficiently understood.

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Summary of Socioeconomic Effects

The results on socioeconomic effects of organic farming in developing countries are mixed. In some situations, organic certification contributes to significant welfare gains. But switching to organic is not always beneficial for smallholders and should therefore not be considered a general strategy for poverty reduction. The benefits of organic production methods tend to be larger in regions where conventional crop yields are low, due to farmers' limited access to modern inputs and production technologies. With better access to markets and technologies, yield gaps between organic and conventional production increase, and the benefits of organic production tend to get smaller.

However, the evidence on causal effects is still limited. Most available studies use cross-section observational data, and not all control for possible selection bias (exceptions include Bolwig et al. 2009, Chiputwa et al. 2015, Ibanez & Blackman 2016, Kleemann & Abdulai 2013, Weber 2011). Very few studies use panel data models (Meemken et al. 2017a), and to our knowledge, no study thus far has used randomized experiments to evaluate the socioeconomic impacts of organic farming in developing countries.

One aspect that needs to be kept in mind is that much of the research in developing countries involves case studies of communities where organic farmers received support through specific development projects. Project support typically includes intensive training in organic agricultural practices, facilitation of links to certified markets, and sometimes financial subsidies (Chiputwa et al. 2015, Jouzi et al. 2017, Stolze & Lampkin 2009). Hence, even when farmers benefit significantly under such conditions, upscaling of these benefits will be difficult, unless the same intensive support is provided to other farmers and communities as well. Organic farming is not a practice that spreads automatically in developing countries simply by other farmers copying what successful early innovators have done.

Another important aspect to remember is that most organic farmers in developing countries so far produce cash crops for the export market. Results from these examples cannot be transferred to the production of food crops for the domestic market. Positive socioeconomic effects for farmers are most likely when significant price premiums for organic products can be obtained. While some high-income consumers in developing countries are willing and able to pay more for organic foods, many domestic consumers are poor and unable to pay significant price premiums.

Conclusion

Farmers need to be educated on the need-based application of agrochemicals to promote discriminate use of these chemicals. Various strategies are suggested to effectively manage agrochemical use. Some of them are:

- Ensuring environmental and ecological compliance
- Identifying non-target species for each region and protecting them
- Mandating the monitoring of toxic remains in plant parts, animal-based food and environment
- Defining Good Agricultural Practices (GAP) for each crop with respect to the agrochemical usage

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- Establishing Maximum Residual Limit (MRL) for each agrochemical
- Detoxification and degradation of chemical residues in the environment

Emphasizing and educating about the occupational and consumer risks associated with the chemicals.There is as much risk associated with the use of agrochemicals as the benefits. First and foremost is the harm they cause to humans and the environment. Use of pesticides in agriculture is inevitable as discussed previously. However, their non-judicious use is posing a great risk to human health as well as the environment. The pesticide molecules are inherently toxic. And most of them are broad-spectrum in nature resulting in the emergence of resistant species. Hence it is essential to develop molecules with selective toxicity. Instead, their biological counterparts need to be discovered and applied to alleviate the toxic effects.

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