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Agricultural intensification, dietary diversity, and markets in the global food security narrative

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1. Introduction

Over the last few decades, calls for agricultural intensification in developing countries have come from many actors, with different motivations, across multiple scales. At the global scale, many agricultural scientists and food security experts claim that intensification is necessary to feed a growing population (FAO et al., 2017; Hunter et al., 2017; Tilman et al., 2011). Many conservationists also advocate for intensification, claiming that it is necessary to conserve biodiversity by preventing agricultural expansion into natural habitats (Garnett et al., 2013; Godfray et al., 2010; Phalan et al., 2011). Donors, development professionals, and national policymakers often see intensification as a way to raise rural incomes and stimulate development (Dawson et al., 2016; Ejeta, 2010; Garnett et al., 2013; Isaacs et al., 2016).

Over the last half century, agricultural intensification has accelerated rapidly, enabling the production of sufficient quantities of cereal crops to feed billions of people across the globe. There is little doubt that this is an important part of the reason why there is a smaller percentage of people who are hungry than ever before in modern history. But while more people now have access to adequate calories, the quality of diets has not been improving at the same rate and, in many cases, has actually deteriorated (Pinstrup-Andersen, 2013). Despite advances in the production of staple crops, there remain around 800 million people in the world who do not consume enough calories, 2 billion people globally who suffer from micronutrient deficiencies and 2 billion adults who are overweight or obese (IFPRI, 2014).

Though the number of people suffering from poor quality diets outnumbers the number suffering from lack of food, narratives addressing food security and agriculture are still dominated by productionist paradigms focused on producing more staple crops and calories, albeit with increasing attention to doing so sustainably (Hunter et al., 2017). In this paper, we argue that a narrow focus on intensification of staple crop production in agricultural and food security policy may lead to unintended negative consequences for the dietary quality of millions of rural communities. We advocate for broadening the focus of agricultural policies and funding to take into account dietary diversity and quality.

Agricultural intensification refers to any process of obtaining more output with fewer inputs (Angelsen and Kaimowitz, 2001), but is most often interpreted as increasing yields per unit of land (Börjeson and Warf, 2010). Intensification is epitomised by the pervasive narrative of the 'Green Revolution' of the 1960s that transformed the agriculture of millions of farms across the developing world (FAO, 2017). Across the planet, agricultural systems that once produced a wide variety of crops employing diverse cropping methods, adopted similar methods of cultivating improved varieties of wheat, rice, and maize using inorganic fertilizers, chemical pesticides, machinery, and irrigated water (Pretty and Bharucha, 2014). Intensification does not by definition imply growing fewer types of crops on a given plot of land, but in practical applications the increased use of these modern methods of agriculture have resulted in a homogenization of agriculture and hence global diets (Khoury et al., 2014). In this paper, we assume that agricultural intensification is generally accompanied by commercialization and conversion to monocrop agriculture, away from diverse cropping and production systems as in the model promoted by the Green Revolution.

While the agricultural intensification model remains dominant, it has endured sustained critique from ecological, global justice, and social justice perspectives. Such criticisms have led to a wide variety of movements and paradigms such as the Food Sovereignty Movement (Jarosz, 2014; McMichael, 2011), the Slow Food Movement (Chrzan, 2004), Local Food movements (Hinrichs, 2003), and Agroecology and Ecological Agriculture (Altieri and Toledo, 2011; Altieri et al., 2012; Scherr and McNeely, 2008; Tscharntke et al., 2012).

Such alternative approaches aim to address the perceived social and ecological impacts and uneven distributional consequences of intensification. This paper does not attempt to arbitrate or reconcile these approaches. Rather, we focus on an often-neglected consequence of agricultural intensification – its impacts on diet quality through

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undermining the nutritional sensitivity of agricultural[1] landscapes.

In the following sections, we describe the agricultural intensification narrative and how it is expressed in national and international policy arenas; and then, lay out the links between dietary diversity and nutrition, between agricultural production diversity and dietary diversity, between markets and dietary diversity, and between agricultural production diversity and biodiversity. Finally, we bring these ideas together to show the implications of these interlinkages for the impacts of agricultural intensification on local diets.

2. The agricultural intensification narrative

Unless there are major changes in global consumption patterns and meat production, in order to feed the world's growing population without destroying remaining forests, the world will need to grow more food without converting more land to agriculture (Berners-Lee et al., 2018; Foley et al., 2011; Godfray et al., 2010). This fact remains the primary justification used for calling for agricultural intensification. Proponents of intensification point to the 'miracle' of the 'Green Revolution' in Latin America and Asia during the 1950s and 1960s. Intensification in these regions, by means of high yielding variety seeds, fertilizer, pesticides, and irrigation was enormously successful in increasing yields of rice, wheat, and maize. When viewed through the prism of crop yields and calorie production alone, it was an unequivocal success. Between 1960 and 2000, yields in developing countries of the three major cereal crops – rice, maize, and wheat more than doubled (Pingali, 2012). The effects upon hunger and malnutrition are astounding, with reductions of hunger in the billions of people, as well as substantial contributions to agricultural economic growth (Haddad et al., 2016).

The success of the Green Revolution contributes in no small part to the dominance of the agricultural intensification paradigm today. Calls for a 'second Green Revolution' are especially dominant in the national and international discourse on agricultural development in Africa where proponents of the 'African Green Revolution' argue that intensification is important not only for food production, but also as a vital driver of economic development. In this view, increases in labor and land productivity resulting from intensification (Collier and Dercon, 2009) are seen as part of a transitional stage towards a non-agrarian urbanised economy (d'Amour et al., 2017; Dorward et al., 2004). Today, most African nations have national productivity growth targets and budget commitments targeting agricultural intensification for economic growth (Ejeta, 2010; Dawson, 2016). International policy makers and donors have also encouraged and financially supported such initiatives (AGRA, 2016; Rockefeller Foundation, 2006; Toenniessen et al., 2008).

From an environmental perspective, agricultural intensification has vastly increased the ecological, energy and petrochemical costs of food production – raising concerns that industrial agriculture is contributing towards overstepping planetary biophysical boundaries (Rockström et al., 2017; Campbell et al., 2017). Moreover, there is little evidence that intensification is associated with reduced rates of deforestation (Rudel et al., 2009; Tscharntke et al., 2012). A recent review found that agricultural intensification rarely leads to simultaneous positive ecosystem services and human well-being outcomes (Rasmussen et al., 2018).

From an equity perspective, many have argued that the Green Revolution and similar technologies are biased towards higher and middle-income farmers and can make the poorest both absolutely and relatively worse off (Niazi, 2004; Pingali et al., 2012). In addition, intensification often leads to the consolidation of small farms leading to the generation of a class of landless, agricultural labourers in place of small- and medium-sized, family farm enterprises (Bernstein, 2010) and a 'corporate food regime' dominated by trans-national agro-food corporations (McMichael, 2005). A parallel argument often made by those in the global justice movement is that – given that the world produces more than enough food to feed its population (Berners-Lee et al., 2018; Conway and Toenniessen, 1999) – it is not the scale of production of food that is the main cause of undernutrition, but its global and national distribution (Berners-Lee et al., 2018; Sen, 1982).

Intensification models and narratives have been used to support many national level policies that have been documented to have adverse consequences on the nutritional sensitivity of food systems. For example, in Rwanda, farmers report that strict rules of the Crop Intensification Program of the government's Strategic Plan for the Transformation of Agriculture, has made it difficult for them to produce crops they need to maintain dietary diversity (Isaacs et al., 2016). Moreover, recent research has demonstrated that the system promoted under the Crop Intensification Program only results in better yields of maize and beans under certain conditions (Isaacs et al., 2016). Similarly, Malawi's entry into the "New Alliance for Food Security and Nutrition", a key aspect of the national policy on Food Security and Nutrition, included a commitment to increased private sector investment in the agriculture sector, increased value added agro-processing, and increased sale of agricultural inputs, leaving critics wondering what aspects of food security or nutrition were actually being addressed (Patel et al., 2014). National policy for food security and nutrition, such as these and many others, often end up justifying commercial scale production of non-food or crops such as tobacco in Malawi (Patel et al., 2014) or palm-oil for biofuel in Indonesia (Neilson and Wright, 2017) leading to loss of diversity within the system with negative outcomes for farmers' dietary diversity (Isaacs et al., 2016).

Sustainable Intensification (SI) has grown out of wide-spread acknowledgement of the environmental shortcomings of the first Green Revolution particularly with respect to its dependence of energy intensive agro-chemicals and its impacts upon biodiversity (Pretty, 2008; Royal Society, 2009). In particular, SI places a strong emphasis on those aspects of environmental damage likely to cause future yield declines (e.g. soil fertility, water availability), thus SI aims to ensure that the benefits of intensification are sustainable – rather than offering an alternate path to sustainability. The sustainable intensification movement is becoming the mainstream alternative to the industrial intensification model and is cited in most 'green growth' targets and initiatives (OECD, 2011; UNEP, 2011; World Bank, 2012; UNCSD, 2012). The term sustainable intensification has become loosely used, resulting in a wide-range of definitions and understandings (Garnett and Godfray 2012; Duru et al. (2015), but its basic objective is to increase yields without harming the environment (Pretty et al., 2014). Even if SI were to achieve this objective, however, it still would not

address the fact that the current global agricultural system does not provide the foods necessary for nutritionally adequate diets. Sustainable intensification is in theory crop agnostic, but perpetuates an overwhelming focus on increasing the production of staple crops primarily grown in monocultures– albeit in less environmentally damaging ways (Pretty and Bharucha, 2014).

3. Food security, nutrition, and dietary diversity

The most widely accepted definition of food security states that food security exists when "…*all people, at all times, have physical and economic access to sufficient, safe and* ***nutritious food*** *to meet their dietary needs and food preferences for a healthy and active life*" (World Food Summit, 1996). In order to be food secure, people need to consume a balanced diet, sufficient (but not excessive) in terms of calories and with adequate nutritious food. Thus it should be clear from this definition of food security that production and consumption of staple crops is not enough to guarantee food security.

[1] Agriculture is considered to be nutrition-sensitive when it seeks to address the underlying causes of malnutrition by focusing on production of nutritionally rich foods and diet diversity (fao.org/icn2).

In response to the climbing global rates of overweight and obesity (IFPRI, 2014), as well as clear evidence linking consumption of certain foods and health outcomes (e.g. fruits and vegetables, or processed and red meats), many in the international nutrition community are pushing for a renewed focus on dietary quality and diversity. Dietary diversity scores have emerged as simple metrics that can be used as proxies of dietary quality. Two of these metrics—the Minimum Dietary Diversity for infants and young children (WHO, 2008) and the Minimum Dietary Diversity for Women (FAO and FHI 360, 2016)—have been validated as indicators of diet quality based on the strength of the association between these indicators and the probability of consuming adequate amounts of selected micronutrients (FANTA, 2006; Arimond et al., 2011). Nutritionists at the FAO have been key players in the development of these measures of diet (Kennedy et al. 2011). Yet the FAO still measures "food security" in terms of the sufficiency of national-level food supplies relative to estimates of national level calorie requirements, as it has since the 1970's (FAO, 2012; Jones et al., 2015). While this is undoubtedly an important facet of food security and useful because it is relatively easy to measure, its use has likely perpetuated the idea that in order to improve food security, the focus should be on national production of more calories instead of producing a diverse range of foods to encourage diversity in diets.

4. Production diversity and diet diversity at the household/farm level

Theoretically, at the household or farm level, it is possible to have positive, neutral, or even negative associations between agricultural production diversity and dietary diversity. If households produce for their own consumption and do not engage in market transactions, then the relationship would be positive – i.e., if the household eats only what it grows, and a diverse set of foods is grown, it can be inferred that a diverse set of foods is consumed. If, however, markets function well and there are zero transactions costs in buying and selling food, there is little reason to expect an association between what a farming household produces and what it consumes. As with any product, the household will produce in order to maximize its profit, thus selling its products for cash and with that cash, purchase food. This would result in a neutral relationship. If a household's yields increase with specialization, then it is possible that growing many crops will actually reduce its overall profits, lowering income with which to purchase foods and potentially reduce dietary diversity. Assuming that a household has the same dietary preferences irrespective of production techniques, the actual relationship will be determined by the degree of market integration with the accompanying transactions costs and the characteristics of production technology – i.e. whether or not there are gains from specialization. It also possible that there are complementarities in production so that yields for some crops may increase if they are planted together – e.g., maize and leguminous crops. This would imply that there could be a loss in profits and income if a farmer were instead to specialize and focus on producing fewer crops resulting in a loss of both agrobiodiversity and income and therefore a likely decline in dietary diversity.

In the last few years, several important papers have been published which investigate these relationships empirically (Sibhatu et al., 2015; Kumar et al., 2015; Powell et al., 2015; Koppmair et al., 2017; Hirvonen and Hoddinott 2017; Jones 2017a). Jones (2017b) systematically reviews these papers and concludes that agricultural production diversity has a small but consistent positive impact on dietary diversity. Sibhatu and Qaim (2018) conduct a meta-analysis on 45 peer-reviewed and non-peer-reviewed studies and find that while 60% report positive associations between production diversity and dietary diversity, most of these are only for a subset of the data in the respective studies suggesting that local context is extremely important (see Hattersley et al. this issue). The specific ways that local contextual variation affects the relationship between production and dietary diversity is not yet well understood.

Jones (2017b) reviewed six studies on diet diversity which included a measure of market access in addition to production diversity; five out of the six found a positive statistically significant relationship between market access and dietary diversity in at least some of their models, but almost all used different measures making them difficult to compare. This generally positive relationship has led some to propose that development dollars would be better spent improving market access for rural households than promoting diverse agricultural productions systems (Sibhatu et al., 2015; Koppmair et al., 2017). Yet, to date, the metrics used to assess market access are crude and do not reflect the scale of investment likely needed to adequately improve access to markets for low-income farmers and consumers. Such proposals necessitate close attention to the role of markets in shaping diets and the importance of agricultural biodiversity at the market and foodshed scale.

5. Production diversity, the market, and the foodshed

It is likely that the importance of markets for diets is contingent on what type of market system is used and how well it is functioning. To date the debate on the relative importance of markets and agricultural production diversity has painted markets as a uniform "black box", with little attention to the role of local markets in redistributing foods from across the foodshed, the role of markets in shaping food preferences, or, the vast diversity of "markets".

Markets are a diverse set of institutions, ranging from very basic sites of barter or exchange to sophisticated markets for derivatives. For example, across much of Francophone Africa there are well-established traditional markets that are described in anthropology as "Bazaar Economies" (Geertz, 1978). These traditional markets of Francophone West Africa are significantly different than markets found in parts of Anglophone South and East Africa, for example. Different market institutions are governed by very different sets of social norms, governance structures and social relationships; these can shape food preferences and transmission of knowledge, making it problematic to extrapolate recommendations from one type of market system to another.

Markets are a key component of a foodshed, acting as one of the main places where food moves from producers to consumers (Peters et al., 2008), but the ways in which they do this and the types of foods that move through them will vary with culture, infrastructure, and connectivity with other places. Nutritionally important foods such as fruits, vegetables and lean animal source foods tend to be much more perishable than staples and processed foods. Less perishable foods can flow relatively easily from regional and even international markets into local markets and shops for local purchase. In settings with limited infrastructure (e.g. refrigeration and transportation), however, the foods most important for diet quality and dietary diversity must come from a relatively short distance (Fig. 1). In such settings, the diversity of the local production systems that flow into the market system is important to the diets of local people. When fruits and vegetables must be produced within the local foodshed, agricultural intensification and a loss of these foods from the productions system will likely impact the availability and price of these nutritionally important foods (Fig. 1).

The configuration of production at the landscape scale is also important. A situation where farm products are exported and market foods imported (e.g. in cash crop growing regions) is likely to have different dietary implications for local communities than a situation where markets contain a mixture of locally produced and imported foods (e.g. where some farmers specialize in cash crops and some farmers sell to local markets). These two scenarios might exhibit similar degrees of average market integration, but have very different foods available for local consumption and thus result in different dietary patterns. While agricultural intensification through cash crop production may allow a farmer with market access greater purchasing power, if there are no

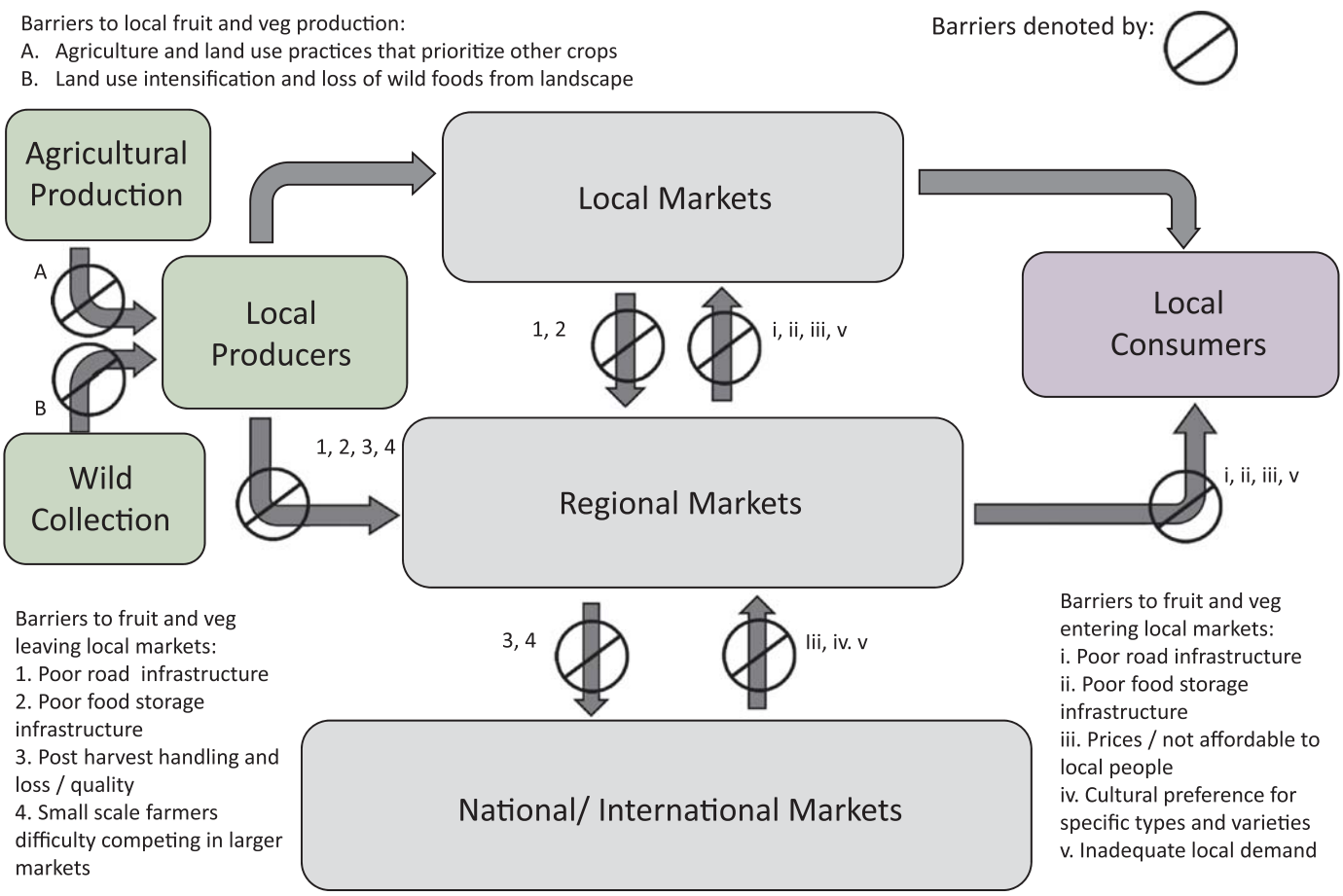

Fig. 1. Flow of Fruits and Vegetables through Foodshed.

farmers in the foodshed growing nutritionally important foods, then the availability of such foods may be low and the cost may be high.

In settings where the majority of the fruits and vegetables available in the local market are produced locally, production diversity may also help to extend the seasonal availability of local (and affordable) fruits and vegetables (for example (Kehlenbeck et al., 2013)).

Markets also have a role in shaping consumer desires and preferences (Hawkes, 2002). While the link between markets and consumption behaviours have long been studied with reference to obesogenic environments in high income countries, only recently have researchers also begun investigating the role of markets in shaping consumer preferences in low- and middle-income countries. Markets are one of the most common places consumers are exposed to advertising and other sources of information that shape food preferences. Such exposure over time shapes food choice through preferences and intentions (Clary et al., 2017). "Markets and other economic institutions do more than just allocate goods and services: they also influence the evolution of values, tastes and personalities" (Bowles, 1998). Markets are a key site for learning new food information and adopting new food preferences which is important because almost all human food preferences are acquired. Markets are also a medium for information and cultural exchange that may affect food preferences. A study from rural Morocco suggested that markets are a key site at which people exchange information about traditional and wild vegetables (Powell et al., 2014). Thus, consumption from own production and from markets should not be seen as completely separate processes, but can be interlinked particularly at the landscape and foodshed levels. A combination of production diversity at the foodshed level along with better infrastructure to support market access is likely to be the best combination in ensuring household access to diverse diets.

6. Agricultural intensification, biodiversity and diets

Conservationists have long been concerned about the impact of agricultural production on biodiversity and ecosystem functioning. As such food production and conservation have historically been viewed as mutually exclusive. Such views are reinforced by the fact that the majority of ecologists and conservation biologists focus on biodiversity conservation in non-agricultural ecosystems – despite the fact that the majority of the world's biodiversity occurs outside of protected areas, often in complex, multi-functional landscapes largely managed by smallholder farmers (Herrero et al., 2017). Such a narrow focus fails to recognize the role that biodiversity plays in maintaining agricultural production, as well as the fact that diverse agricultural landscapes produce a diverse range of foods.

Food production depends on healthy functioning ecosystems that provide services to agriculture (Sunderland, 2011). Most of the ecosystem services that support agriculture, are not necessarily found in protected areas or other areas of contiguous natural habitat, but within agricultural landscapes themselves (Fischer et al., 2008; Zhang et al., 2007). Agricultural intensification reduces biological and landscape diversity, and this in turn can reduce the degree of ecosystem services

that support agricultural production (Loos et al., 2014). This can have negative consequences where ecosystem services are critical for agricultural production (Altieri 1999). Pollination is one such ecosystem service provided by biodiversity (and particularly important for the production of fruits and vegetables). The role of ecosystem services for pollination is consistently underestimated (Reed et al., 2017) yet is of immense global value (Hanley et al., 2015). In addition, the roles of biodiversity in nutrient and water cycling, climate regulation and other ecosystem benefits, while not wholly understood, are becoming increasingly regarded as key to agricultural production (HLPE, 2017). Thus, diversity at both the farm and landscape levels is essential to support and sustain food production (Swift et al., 2004).

Attention to the fact that diverse agricultural landscapes are essential for agricultural production, alters the perceived trade-off between agricultural production and biodiversity conservation prevalent in the literature. Some ecologists propose that intensification of agriculture would allow more land to be available for conservation whilst meeting staple crop production targets (Phalan et al., 2011). These "land-sparing" approaches are usually premised upon calculations of total agricultural production in units of calories produced or total yields or, yields of a small number of staple crops (Phalan et al., 2011) and have rarely been tested on non-staple nutritionally important crops needed to assure dietary diversity. It is essential that local people retain access to diverse foods needed to support adequate dietary diversity and quality – and in many cases, sparing land for conservation can preclude such activities if community access to these lands is restricted (HLPE, 2017).

Agricultural intensification also impacts "semi-wild" lands important for both biodiversity, ecosystem service provision and diet. Intensification often involves multiple harvests of the same crop from the same plot, reduction of fallow lengths and occasionally the loss of fallows altogether (Padoch and Sunderland, 2014). This fallow period can range from three years to thirty (Ickowitz, 2006). Fallows are 'semi-wild' lands which can be very important sources of nutritious foods. In Laos, a loss of fallow land and agricultural intensification was associated with a lower consumption of wild foods (Broegaard et al., 2017). In some regions, wild foods provide the majority of fruits, vegetables, and animal source foods, to local diets (Powell et al., 2015). Wild animal source foods provide essential sources of micronutrients that might otherwise be lacking in local diets (Golden et al., 2011).

The production of food needed to meet nutritionally adequate diets depends on healthy ecosystem functioning which in turn is dependent on diverse landscapes and diverse farm systems. While in certain cases, there may be cause for protecting "wild" areas of nature – for both conservation and ecosystem service provision reasons – the majority of ecosystem service provision occurs within agricultural landscapes. Diverse landscapes that incorporate agrodiversity, biodiversity, and fragments of wild lands in an agro-ecological matrix are essential for the long-term sustainability of the food system (Perfecto and Vandermeer, 2010). Furthermore, for the reasons discussed, these landscapes are also more likely to generate the diverse range of foods needed to meet the dietary needs of a growing population. Such landscapes are unlikely to be created through continued pursuit of the intensification model – "sustainable" or otherwise.

7. Discussion and conclusions

When dietary quality rather than caloric adequacy is considered, it is not clear that intensification necessarily leads to improved diets. The policies of the Green Revolution may no longer be adaptive in a world experiencing a nutrition transition and where micronutrient deficiencies and overweight/ obesity both outnumber hunger by a ratio of over 2:1 (Pingali, 2015; Patel et al., 2014). This appears to be true both for farmers producing food as well for those reliant on market systems that are increasingly homogenised.

Some studies have shown that when agricultural intensification consists of a transition to market-oriented agriculture and cash crops, it can result in poorer food security and/or nutrition (Anderman et al., 2014; Dewey, 1981, 1989). de Walt (1993) suggests that the impacts of commercialization on nutrition are mediated by the type of crop, control of income, maintenance of subsistence production, land tenure, and larger market factors. These mediating factors are key for understanding how to design policies that create win-wins. There may be isolated, specific contexts where win-win scenarios are possible, but these must be determined on a case by case basis. One example in the literature is a case from northern Tanzania (Mt. Meru) where cash cropping did not have a negative impact on nutrition because the cash crop, coffee, was grown intercropped with bananas and, intercropping had a positive impact on nutrient adequacy ratios (Lev, 1981). Zimmerer (2013) similarly finds that intensification of peach farming as a cash crop in the highlands of Bolivia did not reduce agrobiodiversity of maize which he attributes to specific conditions of resource access, ecological conditions for growing the different crops, and local knowledge and skills.

Empirical results from across communities in many countries show a consistent link between the diversity of crops produced on a farm and the diversity of the diets of the farming households (Jones, 2017b). Papers reviewed by Jones (2017b) that also show a positive association between market access and dietary diversity, may be interpreted by some, to suggest that increased agricultural intensification and market integration are the best pathway to improved diets and nutrition. But caution is warranted here before jumping to policy conclusions since several of these papers find varied results when using different measures of market access and different dietary diversity scores; even when these are the same, country-level results are quite heterogenous (e.g. Sibhatu et al., 2015). Out of the five papers reviewed by Jones (2017b) that found statistically significant associations between market access and diet diversity, three use the DDS_12 measure which is biased towards markets (since sugary foods and most beverages and condiments are more likely to be found in markets) and not indicative of healthy diets for individuals (Jones, 2017b; Verger et al., 2017). Furthermore, smallholder farmers in low- and middle-income countries often hedge risk by growing one or more crops primarily for subsistence consumption, while cultivating additional crops for cash income (Wiggins et al., 2011). Agricultural diversification can thus be consistent with market engagement, but rapid transitions to wholly commercialized agriculture may leave many farming families vulnerable to increased food insecurity, particularly in areas with poorly functioning markets.

This does not mean that markets are unimportant for healthy diets. In many places, markets are not only beneficial, but necessary to provide access to foods that are not locally available or that can be produced much more efficiently elsewhere. For thousands of years, humans have produced and traded according to their comparative advantage and markets have enabled this to occur. Arguments in favor of agriculturally diverse farms are not arguments against markets. Markets can be critical for giving farmers access to cash and can (although do not always) enable households to increase their income. While this is clearly beneficial for households, nutritional outcomes do not necessarily improve with higher incomes (Herforth and Ahmed, 2015). Thus, markets should not be seen as a substitute for production diversity at a foodshed scale.

Herein we have argued that within foodsheds, less production diversity could reduce the availability of foods necessary for a diverse and healthy diet in local markets. If agricultural intensification is accompanied by loss of production diversity in the foodshed, diversity that markets might currently provide would likely decline. Particularly in areas where infrastructure is not highly developed, importing healthy perishable foods (fruits, vegetables, animal foods) from long distances would likely be impractical and current prices would not be good indications of future availability as local supply would decline and demand rise. More research needs to be undertaken in rural areas of developing countries to investigate what foods are available in different

foodsheds and the distances different types of foods travel in order to forecast the potential impacts of specialization and intensification on functional dietary diversity.

If the promotion of intensification by development professionals, donors, and national governments leads small farmers in developing countries to convert their traditional complex polyculture farming systems to less diverse, high-input intensive production, it is important to consider potential unintended consequences on local diets. It is possible that the same decisions to intensify would be taken, but at least the implications would be better thought through and possibly addressed (for example, by holding back from complete conversion and maintaining some diversity). Alternatively, researchers and policy makers could embrace complex systems and work with small farmers to increase the productivity of their polycultural systems instead of prioritizing improving yields of the big staple crops. Donors could increase funding for research and investments in improved technologies for fruits, vegetables, and orphan and underutilized crops (http://africanorphancrops.org) to increase productivity while maintaining variety. Policies that support and prioritize small scale farms, over large-scale commercial agriculture must also be central.

We do not claim that intensification is never positive for diets, nor that it won't be an essential aspect of progress towards reducing global burdens of malnutrition. Naturally, there will be times where some form of intensification is desirable in order to produce more food and to raise incomes. Undoubtedly there are better technologies for producing more food which will work in some places, with some combination of foods, with fewer negative ecological consequences – this may be either through more labor or through capital-intensive methods which are locally appropriate. Agricultural science and extension can have important roles to play in ensuring better food and nutrition security, but agricultural intensification should not be advocated everywhere at all times as a 'global mantra'. Decisions about intensification should be taken with some knowledge of the context of the local food system and should also focus on foods other than staple crops if locally appropriate. A preliminary assessment of what foods could potentially be lost from local food systems under intensification strategies and how complementary policies could be adopted to address these losses would be a good first step before any new activities are implemented.

Transforming complex diverse mixed-crop agricultural production systems to commercially oriented intensive agricultural systems will have profound impacts on landscapes, livelihoods, and diets. Advocates of 'sustainable intensification' have called for strategies to intensify production to produce more food, while reducing environmental impacts of intensification techniques; this is a great step towards looking beyond the narrow goal of only producing higher yields. The next step toward ensuring a healthy planet with healthy people is to understand that to end malnutrition, we do not simply need to find ways to produce more calories, but we need to find ways to ensure that we produce enough of the types of food needed for diverse nutritious diets. If intensification is to be part of this solution, it needs to not only be truly 'sustainable', but 'nutrition-sensitive' as well. When policies and programs are implemented that fail to consider this important dimension of food security, there is a risk that they will do more harm than good.

Declaration of interest

I wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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