Courant Research Centre
'Poverty, Equity and Growth in Developing and Transition Countries: Statistical Methods and Empirical Analysis'

Georg-August-Universität Göttingen
(founded in 1737)

Discussion Papers

No. 178

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June 2015

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Economic and ecological trade-offs of agricultural specialization at different spatial scales

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Abstract

Specialization in agricultural systems leads to trade-offs between economic gains and ecosystem functions. Economic gains can be maximized when production activities are specialized at increasingly broader scales (from the household to the village, region or above), particularly when markets for outputs and inputs function well and allow specialization as well as high levels of food security. Conversely, a tendency toward specialization likely reduces biodiversity and significantly limits ecosystem functions at the local scale. When agricultural specialization increases and moves to broader scales as a result of improved infrastructure and markets, ecosystem functions can also be endangered at broader spatial scales. Policies to improve agricultural incomes through improvements in infrastructure and the functioning of markets thus affects the severity of the trade-offs. This paper takes Jambi province in Indonesia, a current hotspot of rubber and oil palm monoculture, as a case study to illustrate these issues. In doing so, it empirically investigates the trade-offs between economic gains and ecosystem functions for three spatial levels of scale (i.e. household, village, and region) and discusses ways to resolve these trade-offs.

Keywords

Ecosystem services, economies of scale, Indonesia, monoculture, oil palm, rubber

1. Introduction

For poor smallholder households that depend largely on the use of natural resources for their livelihood, increasing agricultural incomes is critical to escape poverty (Klasen et al., 2013; Lipton, 2005; World Bank, 2007). In an environment of well-functioning markets and infrastructure, often a first-best economic option is to specialize in the most profitable crop for given soil, climate, and weather conditions (Lambin and Meyfroidt, 2011; Ruiz-Perez et al., 2004). At the same time, there are some costs and constraints to complete specialization which partly relate to the availability, access, and functioning of markets for inputs, outputs, labor, and credit. For example, complete specialization often requires highly seasonal labor demand which often cannot be procured locally; similarly, concentration on one crop exposes farmers to high risk against which they can only imperfectly insure themselves; third, jointness in production can also lead to advantages of diversified production (Allen and Lueck, 1998; Ballivian and Sickles, 1994; Klasen and Waibel, 2012; Kurosaki, 2003). However, the better labor, capital, insurance, input, and output markets function, the lower are these constraints to complete specialization. If, for example, seasonal labor demand can be met with labor migrants, farmers have access to insurance, and improved infrastructure promotes intra-regional and international trade in competitive input and output markets, these constraints to specialization at increasingly broader scales are much less serious (Kurosaki, 2003). In the extreme, this could lead to monocultures not only at the level of the individual household, but at the level of the village, or even region. Hence, the degree of specialization may change along spatio-organizational scales depending on market functioning (Fig. 1).

At the same time, there can be substantial ecological and also socio-cultural costs in terms of reduced ecosystem services if such monoculture agricultural systems emerge at the level of a village or an entire region. There might be losses in plant and animal biodiversity (Foster et al., 2011), but also reduction of pollination services (Priess et al., 2007) or biological pest control (Stamps and Linit, 1997) as well as hydrological functions (Comte et al., 2012; Nedkov and Burkhard, 2012; Ojea et al., 2012). Decomposition services and carbon sequestration may possibly be impaired, too. Furthermore, cultural or information functions may be lost (Gasparatos et al., 2011; Millennium

Ecosystem Assessment, 2005). These losses crucially depend on the level of scale at which specialization on monoculture crops occurs, with specialization at broader scales generating more problems. There can also be a mismatch on a temporal scale: In the short term, the progressive loss of ecosystem functions and associated services may only have a small impact on the profitability of specialized monocultures, in the longer-term, the sharp reduction or entire disappearance of important functions might undermine the profitability of monocultures at broader spatial scales.

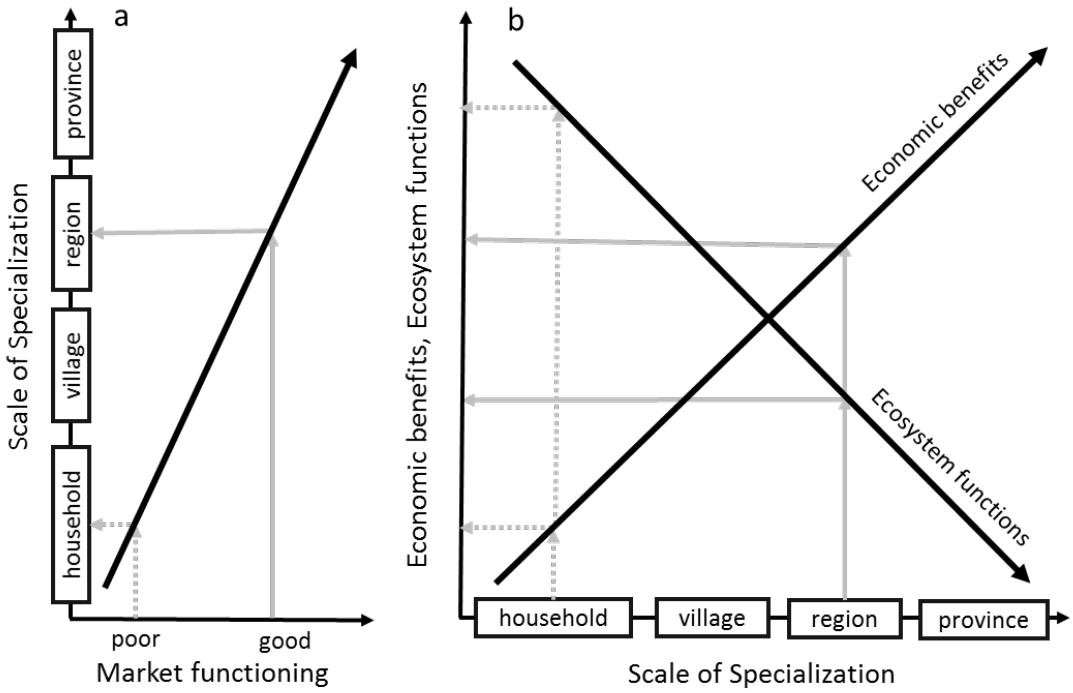

Fig. 1: Market functioning drives the level of scale at which specialization occurs (a), which in turn drives economic benefits and ecosystem functions (b; black arrows). Two scenarios are illustrated (grey arrows): In the poor market functioning scenario (dotted grey arrows), specialization is only possible at the household level (see a) which leads to low economic benefits and high ecosystem functionality (see b). In the scenario with good market functioning (grey line arrows), specialization is possible at broader scales such as the region (see a). This leads to loss of ecosystem functions and high economic benefits compared to the poor market functioning scenario (see b). Note that in this illustration the location of the crossing of the arrows is arbitrary. The general message is that there is a scale-dependent trade-off between specialization and ecosystem functions driven by market functioning.

The economic benefits and socio-ecological and cultural consequences depend therefore, to a large extent, on the spatial scale at which specialization occurs. For example, specialization within a village at the level of an individual farm might already generate many benefits of specialization with relatively few ecological costs if the diversity of crops remains high within a village. Figure 1 illustrates this point by showing two scenarios: one where poorly functioning markets allow only specialization at the household level; economic benefits of specialization are low but ecosystem functions are high. In scenario two, well-developed markets allow specialization at the regional level generating higher benefits but specialization at this broader scale reduces ecosystem services (see also Timmer, 1997). This development of markets and specialization can also be driven by policies. For example, policies can actively promote monocultures through supporting and subsidizing the development of cash crops in particular regions; in the case of Indonesia, the promotion of the palm oil sector was supported by various policies of the government, including migration policies, land policies, infrastructure, etc. (McCarthy and Cramb, 2009). In addition, policies aimed primarily at promoting growth and poverty reduction can also affect this trade-off between economic benefits and socio-ecological and cultural consequences of specialization. For example, policies to improve access and functioning of markets (e.g. through improved infrastructure, information systems) are likely to be beneficial from an economic point of view as they increase the scope for specialization for poor producers, but such policies might cause harm from an ecological point of view as they push specialization to a broader spatial scale.

Some of these issues have been studied individually in both the economics (e.g. Belcher et al., 2004; Hazell and Wood, 2008; Kurosaki, 2003; Ruiz-Perez et al., 2004; Timmer, 1997) and ecological (e.g. Lambin and Meyfroidt, 2011; Smith et al., 2008) literature. Many studies have also commented on the general trade-offs between intensive agricultural production and the loss of ecosystem services (e.g. Evans, 2009; Hazell and Wood, 2008; Lambin and Meyfroidt, 2011; Millennium Ecosystem Assessment, 2005). However, the interplay of specialization and ecosystem functions and services at different spatial scales, and how they are influenced by policy has not been studied at any level of detail so far. The purpose of this conceptual paper is to lay out these issues and trade-offs and illustrate them with examples from the literature and with on-going research on oil palm plantations in the province of Jambi in Indonesia which provides a real-time case study.

2. Optimal Specialization from an Economic Perspective

Economic benefits of specialization are very closely linked with the presence of economies of scale in production. Economies of scale are defined as the advantage of large-scale production that results in lower costs per unit of output (Kislev and Peterson, 1996). Hence, the total production costs are spread over more units of output. Economists tend to distinguish between internal economies of scale and external economies of scale (Hallam, 1991; Marshall, 1920). Internal economies of scale refer to cost advantages that are due to conditions inside the production unit (e.g. the farm or the firm), while external economies of scale relate the cost advantages that arise from greater production of a sector or region (or even an entire economy, Caballero and Lyons, 1990). In the case of agriculture, both internal as well as external economies of scale can be present.

For the case of cash crop agriculture, we identify four most relevant *internal* economies of scale. Firstly, we refer to the specialization of labor. Larger production units can employ workers with more specialized knowledge, for example in the application of chemical inputs (even though this seems not to be the case in our example in Jambi, see section 4). Second, a finer division of labor is possible which might increase the efficiencies of performing tasks and facilitate the monitoring of labor in completing these tasks. Third, internal economies of scale can result through the indivisibility of machines since the use of a more powerful machine, e.g. a tractor, is only profitable for larger plantations. Lastly, the increasing dimension of production can reduce average costs, for example in purchasing chemical inputs or in reducing transportation and processing costs - especially, if distance to input and output markets is high.

Given these potentially large internal economies of scale, the question of optimal farm size arises. If these economies of scale are so substantial, why does cash crop production not take place exclusively on large plantations? And why do smallholders survive in the face of the cost advantages of large plantations? This is because large production units in agriculture also have to contend with substantial diseconomies of scale (e.g. Allen and Lueck, 1998; Binswanger et al., 1995; Lipton, 2005). They are due to the need for large farms to rely on hired labor where principal-agent problems (Levinthal, 1988), information and incentive problems might lead to high costs of monitoring labor and/or low labor effort and productivity. As a result, the family farm has remained a competitive production unit where these information and incentive problems are much less prevalent. As argued by Binswanger et al. (1995), large plantations will prevail if the economies of scale in processing are substantial (as is the case, for example, with bananas and tea) and/or when smallholders cannot easily be linked to larger processing facilities, as is possible in our case study (see section 4). A key message emerging from this discussion is that internal economies of scale generate substantial benefits for farms to specialize on one output, even if it is not optimal for production to take place exclusively on large plantations.

A key driver for *external* economies of scale in cash crop agriculture is the total growth of the respective crop industry in a particular region. This facilitates the development of local processing industries and the development of transportation facilities; both reduce transport costs and promote trade. Growth of the industry in a local area can also help develop and improve the functioning of input, output, and factor markets by ensuring more volume of transactions in these markets which will increase the number of participating actors, thus promoting competition and lowering transaction costs. Lowered transaction costs further promote trade and allow an increasing separation between production and consumption of agricultural households (Timmer, 1997): production is specialized on the most profitable crop given soil and climatic conditions, while consumption of food and other needs is procured through trade.

Despite these substantial scale advantages in production, there are barriers and limits to specialization on one output. One limit can be product-specific. For example, joint production of several outputs can be technically optimal (e.g. in the case of inter-cropping or crop rotation to optimally use existing soil resources or preserve/improve soil fertility, e.g. Ballivian and Sickles, 1994). It may also be the case that local heterogeneity of soil, water, and weather conditions recommend a more diversified portfolio of optimally adapted outputs. Second, there may be an intrinsic value attached to maintaining a diversified portfolio of output, particularly also if these portfolios ensure adequate provisioning of households with the most important necessities and/or the diversified portfolio has itself ethnic or cultural significance. Socio-cultural ecosystem services have been recognized in many studies (de Groot et al., 2002; Millennium Ecosystem Assessment, 2005). Nevertheless, cultural aspects too often have been neglected in the ecosystem services assessment (Chan et al., 2012; Schaich et al., 2010) and therefore the analysis of land-use and landscape development may produce misleading results. Altogether, non-material benefits and intrinsic values such as culture and ethnicity as well as the social embedding or sentimental attachment to places usually constitute limits to specialization.

Apart from these technical and socio-cultural limits to specialization, the main other basic constraint to complete specialization relates to the functioning of markets and the associated transaction costs of engaging heavily with input, output, and factor markets. If transport costs are high and labor markets absent, farmers will be forced to maintain a diversified portfolio of outputs at a local scale that includes all major food necessities (Timmer, 1997). Production decisions will then also be made depending on the availability of family labor; and a diversified portfolio will be beneficial if labor demands can then be spread over the year. Moreover, concentration on one crop can be risky as there are high output and price risks; in the absence of functioning markets for credit and insurance, such risks can devastate farmers if production fails or prices fall (Klasen and Waibel, 2012; Morduch, 1995; Ray, 1999). Since poor farmers live close to subsistence, the absence of well-functioning credit and capital markets will force them to rely on a diversified production portfolio to reduce these risks (Morduch, 1995).

Conversely, this implies that improvements in the functioning of these markets will reduce those constraints to specialization and will enable also smallholder farmers, including poor ones, to specialize much more. They can then increasingly rely on credit and insurance markets to deal with production and price risks, they can rely on labor markets to deal with seasonal labor demand problems, and they can ensure reliable access to food and other needs through trade. Of course, these markets will never function perfectly but the point to emphasize here is that as the functioning of these markets improves, specialization becomes economically more attractive. Moreover, specialization can then move to a broader spatial scale. In particular, if input, output, and labor markets improve substantially, complete specialization on one cash crop can move from the household and the village level to the regional or even national level.

A second point of note is that policies that improve the functioning of input, output, labor, capital, and insurance markets are likely to promote this specialization at an increasingly broader scale. Thus, while these policies are beneficial to smallholder producers as they promote higher and more stable incomes, they will come at a cost of increasing specialization and monocultures at broader spatial scales with important consequences for ecosystem functions and services.

3. Ecological consequences of specialization at increasingly broader scales

Specialization leads to monocultures, and monocultures are usually less beneficial for ecosystem services and associated biodiversity than polycultures. In addition, specialization often leads to intensification which is typically accompanied by higher inputs and the removal of remnant vegetation. A range of ecosystem services can potentially be affected. Most importantly, provisioning services such as crop production may suffer significant losses due to reduced crop diversity (Di Falco et al., 2007; Smith et al., 2008). On the long run, high fertilizer inputs may lead to eutrophication (Tilman et al., 2001) and altered soil physical characteristics and microbial communities. This may in turn reduce production services. Thus, high crop diversity can be critical for achieving food security (Palmer and Di Falco, 2012), at least for subsistence farmers and at local scales. Regulating ecosystem services such as biological pest control may also be more efficient in polycultures or when remnant vegetation is present. For instance, most insect herbivore species have lower densities in polycultures than in monocultures (review on 287 species in 209 studies by Andow, 1991). Complex agronomic multicropping systems have lower pest insect populations than simpler systems (Stamps and Linit, 1997). Temperate forests that consist of multiple tree species have fewer pest outbreaks than single-species stands (Stamps and Linit, 1997). However, supporting services such as soil fertility and regulating services such as nitrogen-use efficiency have been shown to depend more on management than on crop diversity (Snapp et al., 2010). A reduction of coffee yields due to declining pollination services under deforestation may be counteracted by preserving patches of forest (Priess et al., 2007).

Associated biodiversity is often, but not always enhanced in polycultures as compared to monocultures. For instance, polycultures of different annual crops harbored greater weed species richness than monocultures of these crops (Palmer and Maurer, 1997). However, in Malaysia, bird species richness was found to be higher in monoculture oil palm plantations than in polycultures (Azhar et al., 2014), probably due to higher human disturbance during weeding and harvesting in polycultures.

With increasingly broader spatial scales at which specialization occurs, the spatial extent of the resulting monocultures and their ecological effects will also be scaled up. This means that not only crop diversity may be lost over larger areas, but also that landscape configuration might be affected. For instance, technological and environmental factors (e.g. road access, topography) may cause the few crop types to be clustered in space. This heterogeneity may augment the loss of diversity because species that depend on a certain uncommon crop type are less likely to find the remnants of this crop type. Moreover, landscape fragmentation has non-linear effects on species survival, with extinction setting in long before the last remnants of this crop type have vanished (Bascompte and Sole, 1996).

4. Illustrating specialization trade-offs in Jambi, Indonesia

4.1 The case study of Jambi

Indonesia is the country with the largest increase in forest cover loss from 2000 to 2012 (Hansen et al., 2013). At the same time, monoculture cash crops expand rapidly. Since 2007, Indonesia has been the largest palm oil producer in the world (Coordinating Ministry of Economic Affairs, 2011), and it is also the second largest producer of natural rubber. Seventy percent of the palm oil area in Indonesia is located in Sumatra and approximately 42% of palm oil land is managed by smallholders (Coordinating Ministry of Economic Affairs, 2011: 53). Similarly, the majority of the rubber production is produced by smallholders (Coordinating Ministry of Economic Affairs, 2011: 57). The province of Jambi has a total land area of 5,300,000 ha (BPS Provinsi Jambi, 2011: 3) and is a showcase of high dependency on the agricultural sector. The total area under oil palm and rubber cultivation are approximately 936,500 ha and 1,284,000 ha, respectively (Pemda Jambi 2010). The average per capita income in Jambi province is roughly 17.5 million RP/year (BPS Provinsi Jambi, 2011), which is substantially below the national average of 26.8 million RP/year (Kopp et al., 2014: 2). Fifty-two percent of the workforce in Jambi is employed in the agricultural sector. Increase in the number of large plantations has contributed to reducing the area of farmland accessible to smallholders. This has led to forced agricultural intensification (Potter, 2001) and induced agricultural transition (Rigg, 2005). More specifically, subsistence strategies of smallholders in the province shifted from extensive swidden farming to cash crop production. Consequently, 99.6% of rubber in Jambi province are cultivated by smallholders (Estate Crop Services of Jambi Province, 2012) and the cash crops have the potential to increase the economic and social development in the rural areas of Jambi considerably.

Transformation of the Jambi lowland forests started in the 19th century when the Dutch colonial power exploited the natural resources in the region. In the early-1970s, the Indonesian state sold almost the entire lowland rainforests of Jambi Province as logging concessions. While the earlier concessions exploited already existing timber resources, the current ones serve cash crop plantations, primarily oil palm and industrial timber. This change from a predominantly extracting economy to a production economy resulted in the establishment of an agricultural frontier zone where government-led transmigration programs were implemented from 1983 to 2002 to meet the demand for labor force on oil palm plantations (Hauser-Schäublin and Steinebach, 2014: 3f). Migration resulted either from state-organized transmigration projects or from ‘informal rural migrants’ (Bock, 2012) and led to strong increases in population size. The population in Jambi grew from 1.1 million people in 1971 (16 people/km²) to 2.4 million people in 2000 and reached 3.4 million in 2014 (63 people/km²) (Drake, 1981: 473; BPS Provinsi Jambi, 2013: 136 - 137). Between 1967 and 2007 reportedly 96,401 families or 394,802 people were resettled to Jambi by transmigration projects as a measure of poverty alleviation and regional economic development (Pemerintah Provinsi Jambi, 2008). These households received parcels of land (about 2.5 ha each) and contracts with agribusiness companies to cultivate oil palm within a smallholder-contract-system. In summary, land-use transformation in Jambi province is closely linked to immigration because immigration is essentially triggered by the rising agro-business and oil palm economy to which migrants either act as a workforce for plantations or hope to be set up with land and begin production by themselves. In 2012 the share of residents with migratory background reached about 80% (Suara Pembaruan, 2012).

In the case of Jambi, specialization on oil palm or rubber plantations has been considered the (economically) best land-use option because returns to land and labor are higher compared to rubber agroforests (Feintrenie and Levang, 2009) and other non-commercial land-use systems (Zen et al., 2005). While Belcher et al. (2004) found higher returns to land in oil palm plantations compared to rubber agroforests and rubber plantations in East Kalimantan, Feintrenie et al. (2010) observed the opposite in Jambi where returns to land are higher in rubber plantations than in palm oil plantations and rubber agroforests. All authors found higher returns to labor in oil palm than in rubber plantations. However, these plantations rarely provide any non-material benefits or other cultural services, nor do they provide intrinsic values. Interestingly, this coincides with the fact that in the native habitat of oil palms in Western Africa, socio-cultural importance is not related to monocultures but to the palm individual, or parts of it (Atinmo and Bakre, 2003).

On the contrary, non-financial considerations such as ethnic (and thus also migratory) background can play an important role (Belcher et al., 2004): ethnic-specific perceptions of the environment apparently have a serious impact on land and resource management (Pfund et al., 2011; Reenberg and Paarup-Laursen, 1997; Steinebach, 2013). Indigenous households often also depended to a much greater extent on a diverse range of habitats and species than non-indigenous households (Laird et al., 2011). Such livelihood dependency on prevailing land-use systems constitutes an important factor determining land use and specialization.

4.2 Specialization across scales in Jambi

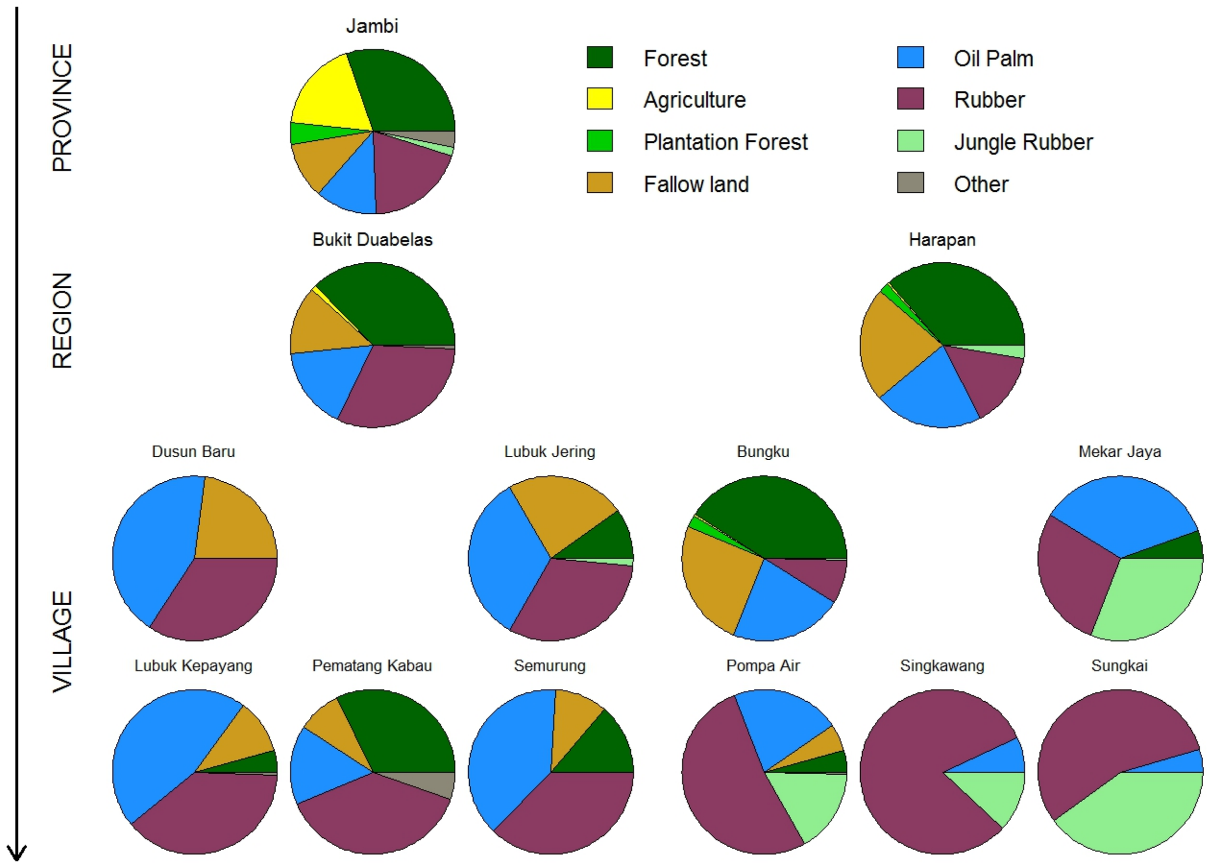

Fig. 2: Land-use types in the province of Jambi in Indonesia in 2011 show that specialization decreases from the fine to the broad scale, i.e. from the village level (five villages per region, bottom rows) to the region level (Bukit Duabelas and Harapan, second row) to Jambi province (top row). Data source: Landsat and RapidEye images analyzed according to Indonesian ministry guidelines (Ministry of Forestry, 2008).

As predicted by our conceptual framework, the level of specialization differs by the level of scale considered (Fig. 2). To assess scale dependence, we analyze land-use types based on the Land Use/Land Cover (LULC) maps derived by visual interpretation (GOFC-GOLD, 2013; Liu et al., 2005) of the most cloud-free mosaics of Landsat and RapidEye images with the guideline of land cover mapping produced by the Indonesian Ministry of Forestry (Ministry of Forestry, 2008, Fig. 2). This analysis does not cover the household level, but the village, region, and province levels. We find that specialization on one or a few crops is strongest at the village level, whereas differentiation increases at the region level and is highest at the province level (Fig. 2). More detailed data are available for the household and village levels from a household survey (N=701 smallholder households in 45 villages) and a village survey (N=98, containing the 45 villages of the household survey) conducted in 2012 in the province of Jambi with structured interviews (Faust et al., 2013). For the present study, we analyze the main land-use types in the area, i.e. oil palm, rubber, paddy, fruits and vegetables. At the household level, we find very strong specialization (Fig. 3a). Most households specialize on a single crop and only very few grow two or three crops. Most cultivated land is owned by pure rubber farmers and by households that focus on rubber and oil palm plantations. Similarly, at the village level, there are more villages that specialize on one or two crops than villages with more land uses (Fig. 3b). However, specialization is much weaker at the village level than at the household level.

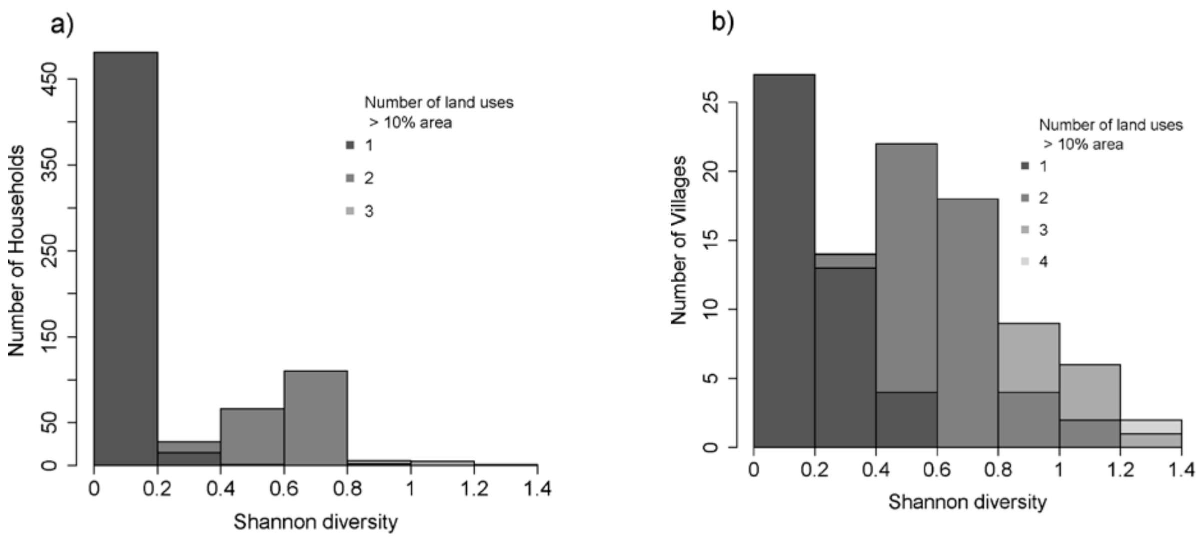

Fig. 3: Number of smallholder households (a) and villages (b) that fall into different categories of Shannon diversity (Magurran, 1988), an inverse measure of specialization. The number of land-use types with a minimum share of 10% of the total cultivated area per household or village, respectively, is indicated in grey shades. Overall, there are more specialized households and more specialized villages than households or villages that grow a diverse portfolio of crops. Specialization is much stronger at the household level (a) than at the village level (b). Data source: own calculation.

Hence, overall, specialization decreases from household via village to province level. In line with our conceptual framework, this suggests that markets are not functioning well enough (yet) to allow a greater specialization at broader spatial scales. At the same time, there is, as expected, already considerable specialization at the household and village levels which appears to be the optimal economic strategy for households (at least in the short term).

To assess to what extent economies of scale drive specialization in the Jambi case study, we take the example of oil palm cultivation and analyze both the production output and the production costs of oil palm farmers. Since output and factor costs differ across plantation age, we categorize the age in accordance to the yield cycle of oil palms into four age groups. For each age group we determine the median plot size and divide the plots into one group with smaller-than-median plot sizes and one group with larger-than-median plot sizes. As has been found in many studies (see, e.g. review by Binswanger et al., 1995; Ray, 1999), output per unit land is larger for small farms (Table 1). This is partly due to more intensive input use (especially labor, but also other inputs) on small plots (Table 1). It can also be due to more intensive and improved use of these inputs as the incentive problems afflicting large farms with hired labor are less prevalent here (see discussion in section 2).

Production costs ae investigated in the form of labor and input costs per hectare and year. Labor comprise operations such as land clearing, pits taking, seedling transportation, planting and replanting, manure and fertilizer application, chemical and manual weeding, harvesting, and pruning and marketing. Inputs costs refer to costs for seedlings, plant and animal waste, soil amendments, fertilizer, herbicides, machinery, and input and output transportation. Results for input and labor costs suggest lower costs for larger-sized plots (Table 1). This is especially apparent for labor costs, and there for immature and young plantations (age groups 1 and 2). However, profits per hectare do not support the existence of economies of scale in our study region. Only for the third age group the profit per hectare of larger plantations exceeds the profit of smaller plantations. Hence, our results for the Jambi case study suggest only weak evidence for economies of scale.

Thus, as discussed in our conceptual framework, we can confirm the finding from many other countries that there are gains from specialization at the farm level but that this specialization does not inevitably lead to a consolidation of smallholder farms to ever-larger units; instead specialization is taking place among smallholders at the household and, as we have shown above, at broader scales as well.

Table 1: Yearly values on mean yield, mean factor costs (costs for labor and inputs) and mean profits of oil palm plots per plot size category for plantations in different age groups. The first age group contains plantation ages 0 to 3 years, because most trees start to produce harvestable fruits in the third year. Further age groups are group 2 (4-9 years), 3 (10-17 years), and 4 (18-23 years). Standard deviations are shown in parentheses. Data source: own calculation.

	Small plantations i.e. </= 50% percentile				Large plantations i.e. > 50% percentile			
Plantation age group	Mean yield [MT/ha]	Mean factor costs/ha		Profit [US$/ha]	Mean yield [MT/ha]	Mean factor costs/ha		Profit [US$/ha]
		Mean labor costs [US$/ha]	Mean input costs [US$/ha]			Mean labor costs [US$/ha]	Mean input costs [US$/ha]	
1	0.23	184.00	114.85	-98.24	0.34	70.28	103.70	138.75
	(1.07)	(271.56)	(121.17)	(930.20)	(1.87)	(91.07)	(98.09)	(1631.33)
2	12.33	409.56	157.13	9680.01	9.88	208.49	132.70	7997.01
	(9.66)	(302.89)	(131.65)	(8095.78)	(7.65)	(239.56)	(111.86)	(6519.13)
3	16.96	425.90	181.18	13809.95	17.30	292.64	203.81	14597.71
	(10.42)	(403.14)	(142.43)	(8705.82)	(8.54)	(401.01)	(164.47)	(7166.60)
4	20.43	377.65	269.59	16720.72	14.56	181.01	94.88	12100.11
	(7.50)	(363.66)	(271.02)	(6311.65)	(6.08)	(80.25)	(69.56)	(5216.16)

4.3 Policy influence on agricultural specialization in the Jambi case study

Two main policies affected the agricultural specialization process in Jambi fundamentally, the transmigration programs and the current master plan of the Indonesian government. The Indonesian government's transmigration program played a key role for the start and spread of oil palm cultivation in Jambi and the significant involvement of smallholder farmers (Gatto et al., 2014). The oil palm cultivation was organized in so-called nucleus-estate and smallholder (PIR-NES) schemes. The government support in terms of technical and financial assistance and land titles provided to the oil palm NES schemes was instrumental for increasing the specialization of transmigrant smallholders on oil palm.

The master plan for Indonesian Economic Development designated Jambi as part of the Sumatra Economic Corridor as a 'Center for Production and Processing of Natural Resources and as Nation's Energy Reserves' (Coordinating Ministry of Economic Affairs, 2011: 46). The economic development strategy for the corridor focuses on three main economic activities: palm oil plantations, rubber plantations, and coal. To support the development of the main economic activities within the corridors the government will contribute around 10 percent the development cost. The remaining costs will be provided by state-owned enterprises, private sector, and through public private partnership (PPP) (Coordinating Ministry of Economic Affairs, 2011: 55). Furthermore, regulatory requirements, infrastructure improvements, technology development and research activities will be supported which will altogether lead to further specialization on palm oil and rubber plantations from the household to the province levels of scale.

Thus, policy has strongly supported specialization directly through the economic development strategy in Jambi and indirectly through the provision of infrastructure and improvements in the functioning of markets. This has surely contributed to raising incomes in the region, but the associated specialization at increasingly broader scale is generating precisely the trade-off that we have discussed above.

5. Conclusions: How can the trade-offs caused by specialization be addressed?

Specialization causes trade-offs between economic benefit and ecosystem functions that increase with the spatial scale of specialization which is in turn determined by market functioning. Since economic benefit and ecosystem functions and services are both legitimate concerns, a solution that satisfies all stakeholders is not straightforward. Such a solution must address the spatial distribution of agricultural production in the landscape, be promoted by policies, and is also affected by the issue of long-term consequences that are not necessarily considered in specialization debates.

Regarding the spatial distribution of ecological and economic functions in the landscape, there are two basic approaches, land sharing and land sparing (Lambin and Meyfroidt, 2011). Under land sharing, some land is set aside for conservation while other land is used intensively for production. Under land sparing, less intensive production techniques are used to maintain some ecological functions (and especially biodiversity) throughout agricultural land (Fischer et al., 2014; Green et al., 2005). The concept of mosaic landscapes with intensive plantations intermingled with both agroforestry zones and high conservation value areas proposed by Koh et al. (2009) constitutes a combination of land sharing (agroforestry zones) and land sparing (intensive oil palm plantations, high conservation value areas). Mosaic landscapes would be especially promising in areas where both large companies and smallholders are present, as is the case in Jambi. Companies with their efficient work schemes would benefit from economies of scale, could engage in intensive plantations and set some land aside for conservation (Koh et al., 2009; Tscharntke et al., 2012). Smallholders may prefer the less specialized agroforestry systems, especially if supported by policy incentives.

Policies should not directly promote specialization, but rather aim at improving incomes, lowering poverty, and safeguarding ecosystem services. This might or might not lead to increased specialization at different spatial scales. Certification programs such as the Roundtable on Sustainable Palm Oil may help to reconcile economic benefits with ecological functions by supporting sustainable production modes. These might include diversification to a certain degree and at some levels of scale. Payment for Ecosystem Service Schemes can more directly support the maintenance of ecosystem services. Taking the example of oil palm, lowland plantation owners could be asked to compensate upland farmers beyond 600 m elevation where oil palm cannot grow for water-related ecosystem services such as provisioning of drinking water and electrical power generation. Moreover, there is no economic justification for promoting inter-regional trade by artificially lowering transport costs. In Indonesia, there are substantial fuel subsidies (Sterner 2011) that are not only costly to the government but increase CO2 emissions from the transport sector (Jakob et al., 2014). They also artificially promote specialization and trade beyond what is economically optimal as the external costs of subsidized transport costs are not considered by actors. For example, for many areas in our case study province Jambi it will be cheaper to source food from elsewhere in Indonesia than produce it locally, allowing even more specialization in palm oil and rubber production. Removing these subsidies and taxing energy so that it reflects the external costs of its use would move specialization to its economically optimal level. It would also then help conserve biodiversity. Thus, removing energy subsidies and taxing fossil fuels would have the quadruple benefit of relieving the state budget, allow for pro-poor expenditure reforms, reduce CO2 emission, and help conserve biodiversity. Such policies might be able to turn the specialization-driven ecological-economic trade-off into win-win situations at least for some spatial scales and over longer temporal scales.

Temporal scales and especially long-term consequences of specialization were not in the focus of this paper, but could provide a worthwhile perspective for future attempts on the topic. Specialization may have long-term costs as it may destroy vital ecosystem services required for the long-term viability of crop production. Furthermore, diversification incentives may lead to a greater sustainability also in economic terms, e.g. via improved biological pest control or pollination services, when considering sufficiently long time horizons. To the extent this is the case, there is a case for government intervention to slow down specialization through zoning and other land-use regulations. This would then also be in the long-term interest of smallholder producers, so that the mostly small-scale specialization-driven trade-offs between economic benefit and ecosystem functions can be converted into win-win situations.

Acknowledgements

This study was financed by the Deutsche Forschungsgemeinschaft (DFG) in the framework of the collaborative German - Indonesian research project CRC990.

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