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ORIGINAL ARTICLE

Homegarden commercialization: extent, household characteristics, and effect on food security and food sovereignty in Rural Indonesia

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Abstract

Homegardens have long been recognized for contributing to household food security, nutritional status, and ecological sustainability in especially poor, rural areas in low-income countries. However, as markets and policies drive the commercialization of food and farming systems, and of rural livelihoods in general, it becomes increasingly difficult for small-holder farmers to maintain homegarden plots. Rather than autonomous spaces to grow food for self-consumption, farmers are transforming the land around their dwellings into an income-generating space by planting commercial crops for sale in urban and processing markets. The objective of this study was to examine homegarden commercialization in the Upper Citarum Watershed of West Java, Indonesia, and its effects on food security and food sovereignty. We employed a mixed-method approach to survey 81 village households involved in agricultural production. For quantitative analysis, we calculated a "homegarden commercialization index," and developed indicator frameworks to examine relationships between commercialization, household food security, and food-related decision-making. Accompanied by insights from qualitative interviews, our results show that homegardens are highly commercialized, which contributes to the spread of monocultural production in the region. We argue that homegardens should be included and supported in food, agricultural, health, environmental, and rural development policy, in Indonesia and generally.

Keywords Homegardens · Agricultural commercialization · Food security · Food sovereignty · Indonesia

Introduction

Around the world and for millennia, small-scale farmers have used plots of land around or near their dwellings to produce vegetables, fruits, herbs, and small livestock for household consumption (Soemarwoto and Christanty 1985). Research demonstrates the importance of these small plots—referred to as homegardens—for small-holder food security and livelihoods (e.g., Kumar and Nair 2004; Rooduijn et al. 2017). Homegardens can provide a stable source of fresh and nutritious food, especially for farm households that produce mostly for the market, and that experience income stress or

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shortfalls during the growing season (Abdoellah and Marten 1986; Mohri et al. 2013; Mattsson et al. 2017; Wright 2014). In addition to contributing to household food security, homegardens also offer the potential to enhance household food sovereignty in otherwise market-integrated agrarian landscapes; even if their crop lands are subject to the changing demands of food markets and government agricultural programs, households can maintain decision-making control over how and what they produce in the homegarden, and how and what they eat from it (Boone and Taylor 2016). For especially poor rural households, homegardens can serve as a buffer against food price shocks, a source of fresh food, and a space of self-determination. As such, homegardens can be important considerations and factors in Sustainable Development Goals 1 and 2 on "No Poverty" and "Zero Hunger", respectively.

In recent decades, however, it has become increasingly difficult for small-holder households in the developing world to maintain homegardens (e.g., Abdoellah et al. 2006). Agriculture has become increasingly commercialized and industrialized, and off-farm pressures have come to dominate food systems across many parts of the globe. To keep up with these developments, policies and markets encourage farmers to industrialize, specialize, and standardize, to engage more directly with buyer–driver commodity chains and the "supermarket revolution," and often, to contract their production (Clapp and Fuchs 2009; Reardon et al. 2012). In this context, homegardens can be seen as a waste of otherwise income-producing space, spurring small-scale farmers to commercialize the land around their homes (e.g., Abdoellah et al. 2006). Beyond the general industrialization of agriculture, precise causes of these changes are not yet fully understood, nor are the long-term environmental, economic, and social impacts.

This paper examines homegarden commercialization in the Upper Citarum Watershed (UCW) in West Java, Indonesia. Here, at the mouth of the longest river in the province, and one of the most polluted rivers in the world, small-scale farmers have been converting their homegardens to commercial and agro-chemical intensive production since the 1990s (Abdoellah et al. 2006). We conducted a mixed-method study in the UCW over a period of 10 months, asking three questions: (1) To what extent have small-scale farmers commercialized their homegardens? (2) What household characteristics influence their choice to commercialize homegardens? and (3) What are the effects of homegarden commercialization on household food security and food sovereignty?

In the context of continuing rural poverty and growing environmental contamination in the region, understanding homegarden commercialization is an important issue for scholars, small-holder farmers, and policy makers. This is especially so given recent government calls to clean the Citarum River (Tarahita and Zulfikar 2018), and the potential contradiction between these calls, and the suite of agricultural policies that focus almost exclusively on increasing production using "modern" production methods including synthetic fertilizers, pesticides, and herbicides that leach into the river. Furthermore, because homegarden commercialization is happening in relation to broader changes in Indonesia's food and farming systems—processes like commercialization, globalization, and industrialization, which are much more general and widespread (Nevins and Peluso 2008)—insights and methods from the study can apply to other contexts where homegardens potentially contribute to household food security and broader sustainability, but where off-farm pressures are propelling their commercialization. Different from research that examines the benefits of homegardens for small-holder households, which we review below, our study examines the losses from *not* growing homegardens.

Homegardens and benefits to small-scale farming households

Cultivating food in small plots adjacent to human settlements and/or households is one of the oldest and most enduring forms of agricultural production (Ninez 1987). Today, while there is no single definition of a homegarden, Galhena et al. (2013) synthesized the following from their extensive literature review. A homegarden can be considered:

> a well-defined, multi-storied and multi-use area near the family dwelling that serves as a small-scale supplementary food production system maintained by the household members, and one that encompasses a diverse array of plant and animal species that mimics the natural ecosystem (2).

In the Upper Citarum Watershed, as elsewhere and especially in tropical climates, homegardens operate as part of agro-forestry systems (Abdoellah and Marten 1986; Christanty et al. 1986). Here, vegetable, fruit, grain, herb, and medicinal crops are grown together with tree species. Researchers argue that in the context of deteriorating family farms, biodiversity loss, soil erosion, environmental pollution, and climate change, homegardens will play an increasingly important sustainable land-use role, now and in the future (e.g., Nair and Garrity 2012). This claim is further supported by research that shows the adaptability of homegarden systems to various land sizes and types, elevations, and topographies, and kinds of crops planted (Jacobi 2016). Furthermore, scholars have shown that homegardens as part of agro-forestry systems can provide economic opportunities such as increased income; social functions such as preserving traditional knowledge and strengthening social capital; environmental benefits in terms of enhancing biodiversity, conserving ecosystems, and storing carbon;

and health benefits in maintaining nutritional needs in especially poor and rural areas. Kumar and Nair (2004), Nair and Garrity (2012), and Galhena et al. (2013) provide useful overviews of homegarden research. To date, studies of how homegardens impact environmental conditions and ecosystem services are most common, while studies of household impacts are nascent.

Homegardens, food security, and food sovereignty

In addition to the general benefits listed above, homegardens as part of agro-forestry systems have been linked to increased food and nutrition security. Molina et al. (1993) demonstrated lower deficiencies of iodine, Vitamin A, and iron in people who ate fruits and vegetables from homegardens in Central America. Galhena et al. (2013) showed that homegardens increased household food security in post-conflict Sri Lanka, and Mattsson et al. (2017) found that homegardens enhanced Sri Lankan food security throughout the year, and at low costs to especially poor farmers. Wright (2014) found that homegardens enhanced food security in the Philippines by increasing access to high-quality food calories in the form of fruits and vegetables. In Indonesia specifically, Abdoellah and Marten (1986) illustrated the link between homegardens and household nutrition, especially in poor and rural areas.

Researchers have also begun to question the role of homegardens in efforts toward food sovereignty. According to the Forum for Food Sovereignty's (2007) Nyéléni Declaration, food sovereignty is:

> The right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agricultural systems. It puts the aspirations and needs of those who produce, distribute and consume food at the heart of food systems and policies rather than the demands of markets and corporations.

Researchers have examined the potential contributions of homegardens to efforts toward food sovereignty in Nicaragua (Boone and Taylor 2016), Bolivia (Jacobi 2016), Niger (Paris 2013), and California in the United States (Gray et al. 2014). These studies concluded that homegardens had the potential to enhance household and community autonomy in the food system, and that policies supporting homegardens are lacking.

The above studies assessed the important relationships between homegardens and food security and/or food sovereignty. They offer insights into how and why homegardens should be supported and expanded to address present issues of hunger, poverty, and environmental degradation, especially in rural areas. Our study takes a different starting point; namely, we focus on the *absence* or *degradation* of homegardens, primarily through their commercialization.

Research methods

Site selection

Our study was conducted in the Upper Citarum Watershed in West Java, Indonesia. The Citarum is the longest river in West Java, stretching 300 km, and providing irrigation for thousands of acres of agricultural land, hydro-electric power, aquaculture resources, and drinking water for Bandung, and Jakarta, the capital city. It is also infamous as one of the most polluted rivers in the world, attracting increased government attention for clean-up efforts (Tarahita and Zulfikar 2018). In addition to pollutants discharged from textile factories operating in the UCW, agricultural industrialization and commercialization—particularly the increased use of synthetic fertilizers, pesticides, and herbicides, and practices that increase soil erosion—also play key roles (Parikesit et al. 2005). Since the 1970s and after the Green Revolution, the UCW has experienced rapid agricultural development, characterized by increased use of agrochemicals, and shifting from home consumption to market production. These trends have intensified in the 2000s along with increased agricultural commercialization in the region, causing major changes in the agricultural landscape, with a strong trend towards homogenization. Today, larger scale farming of commercial crops is displacing the once diversified landscaped of mixed cropping and small-scale home plots: a handful of commercial crops occupy much of the land farmed in the UCW.

The study was carried out in a typical high-altitude agricultural landscape where massive homegarden commercialization has been occurring since the 1990s. We selected the village formerly known as Sukapura village as the study site. The village was administratively divided into two new villages in 2012: Sukapura and Resmi Tinggal (Fig. 1). Despite the split, we treated the two villages as one unit, given their shared history and similar present conditions. Crucially, homegardens were prevalent across households in the aggregate Sukapura village before commercialization began in the 1990s, which was well before the village administrative division in 2012. Today, the socio-ecological characteristics of homegardens are the same across the administrative division. With well-drained and fertile soil, the conditions in the study site offer great natural advantages for cultivating a mix of crops (Abdoellah et al. 2006). Most families rely on agriculture as their primary livelihood. Typical for villages in the Upper Citarum Watershed, poverty is high in the study site. From family welfare data issued by the Family Planning Board of Indonesia (BKKBN), 19% of households (881) in the study site were considered very poor and 47% (2162) were considered poor in 2016 (Village profile documents, 2016).

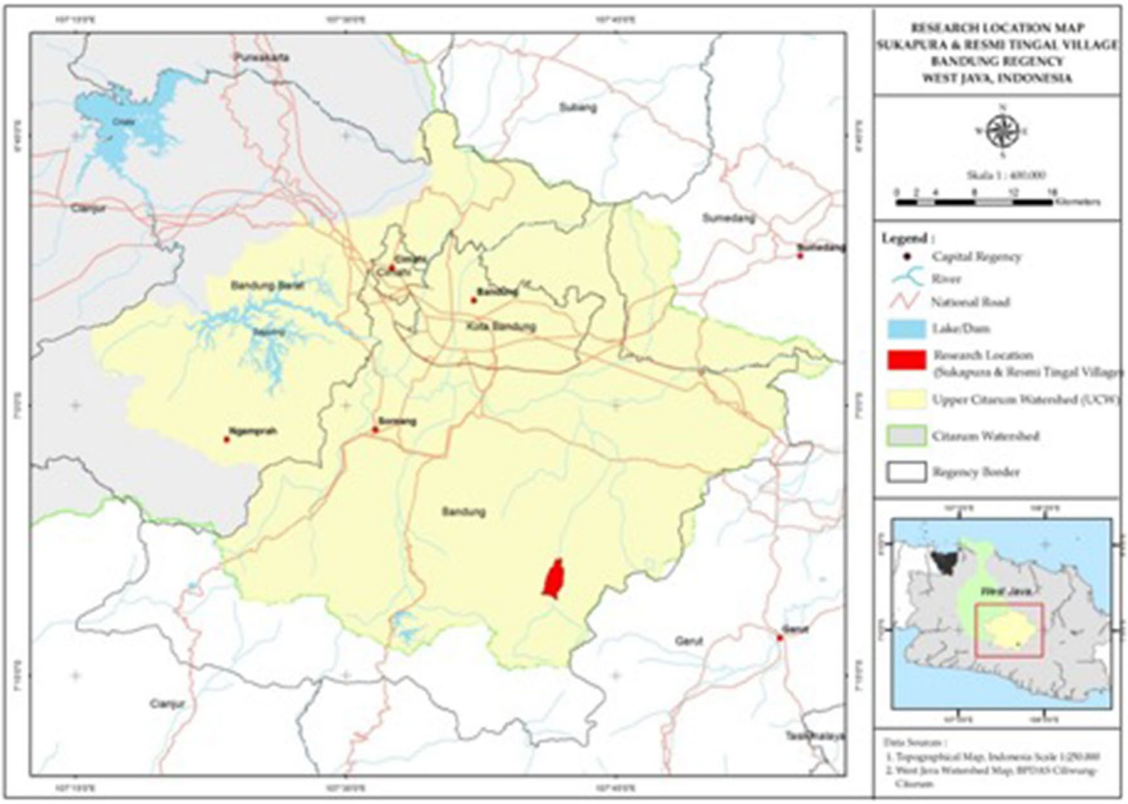

Fig. 1 Sukapura and ResmiTingal Villages in West Java, Indonesia

The study site was dominated by agricultural land, including rice fields, commercial small-scale farms, mixed small-scale farms (*kebun-talun*), and homegardens (Soemarwoto 1984). Villagers by and large operate their agricultural lands commercially, either under contract with a firm, or selling to middlemen, as opposed to producing for home consumption. The study site is located about 30 km southeast of Bandung Municipality, and 20 km from the Majalaya subdistrict, a center of the textile industry in the UCW. An asphalt road connects villagers to Bandung and Majalaya, facilitating the marketing and transportation of their agricultural products; given these conditions—the favourable environment for agricultural production, the high level of commercialization, the transportation infrastructure, and the poverty of local residents.

Sampling design

In this study, we were interested in evaluating the effect of the homegarden commercialization that occurred in the 1990s. Accordingly, our target population included households with homegardens before the commercialization era that took off in the 1990s, and households with homegardens currently. Due to the lack of a sampling frame for the targeted population, we took the following strategy. First, we used the government list of 4798 households in Sukapura and Resmi Tingal villages in 2017 as our sampling frame. Second, to determine sample size (n), we used Lynch's et.al. (1974) formula:

$$n = \frac{N z_\gamma^2 \pi(1-\pi)}{N\delta^2 + z_\gamma^2 \pi(1-\pi)},$$

N is the population size, 4798. z_γ is the normal distribution γ-th quantile. Here, we used a confidence level of 95% which results in a z value of 1.96. δ is the margin of error and we used 10%. And π is the proportion of sub-population understudied (i.e., the households with commercialized homegardens). Since we did not have the information about π and the reliability of sample estimates increase as the increase of sample size (Lohr 2010), we choose $\pi = 50\%$ which provides the maximum sample size and hence the highest reliability. Accordingly, we obtained a sample size of 95 households. Next, we randomly drew a random sample of

95 households from the list. And finally, we threw out households from the random sample that did not fit these criteria. This led to a sample of 81 households, which we used in our analyses. This strategy may not an ideal one, and we are aware that the sample size may under-determined. However, the use of $\pi = 50\%$ might compensate the problem and keep the sample reliability at the defined level.

In addition to administering questionnaires, we also carried out in-depth interviews with 12 informants, who we purposively selected because of their knowledge about homegarden conditions and management before and after commercialization. Interviews with such informants were carried out to obtain initial qualitative information concerning "changes" in homegardens at the village level. These interviews provided important information and insights prior to the administration of survey questionnaires. Because the commercialization era began after the Green Revolution in the 1970s, and intensified in the 1990s, we selected heads of households who were at least 30 years of age as our informants.

Data collection and instruments

Research took place from April to November 2017, using sequential mixed methods. We used a standard questionnaire to survey household heads from 81 households, supplemented with qualitative interviews with 12 informants. The survey included demographic questions (income, education, household size, and land area), and questions about agricultural output and sales, which we used to determine the extent of homegarden commercialization. To examine the effects of commercialization on household food security and food sovereignty, we developed a set of indicators for each (see Appendix A).

For food security, we built indicators based on the Food and Agriculture Organization's (FAO et al. 2017) definition of food security as "A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy lifestyle" (p. 107). The FAO's definition includes four dimensions, which we used as indicators: food availability, economic and physical access to food, food utilization, and stability over time. We populated each indicator with variables for quantification using FAO (2008) definitions combined with insights from Lang and Heasman's (2016) work on *food paradigms*. Lang and Heasman argue that there are currently three competing paradigms about how to grow, distribute, and consume food: (1) a Productionist Paradigm that frames problems of hunger and rural poverty as problems of low production and productivity, (2) a related Life Sciences Integrated paradigm (LSIP) that applies new scientific technologies to productionist logics, and (3) an Ecologically Integrated Paradigm (EIP) that focuses on how human and environmental health are related through practices like agro-ecology. In our study, to measure food security—especially as associated with homegardens—we scored responses that aligned with a Productionist Paradigm (including its LSIP variant) lower than those that aligned with an EIP, since approaches that combine human and environmental health have higher potential for long-term and sustainable solutions that address hunger and especially rural poverty.

Specifically, *food availability* refers to the "supply side" of food security, which we defined in terms of how much food was available from homegardens, from 0 to 100%. *Food access* goes beyond the availability of food at household or national levels, to consider barriers for attaining food: markets, prices, and income are central to the food access category. Because food is accessible in the UCW—increasingly industrially processed foods from market shops—we defined access in terms of what factors people considered most when buying food; buying lots and cheap food was scored lower than buying from local sources, since the former indicates a shift toward industrial diets. *Utilization* of food is related to food quality and the nutritional status of individuals. We were interested to understand how people perceive food quality, as a matter primarily about quantity and price, or about quality and hygiene. For *stability* of food security over time, we used environmental awareness in land management, and the kind of knowledge used to cultivate homegardens as variables. Our assumption, based on Lang and Heasman, the FAO, and others, was that achieving and maintaining food security in the long term will depend on taking care of the environment, and using forms of production and knowledge that recognize the interconnectedness of human–nature systems.

While the FAO definition of food security is generally agreed upon,[1] and is repeated in international and national policies, food sovereignty is perhaps more contested, with different understandings and applications in public and private, and community and national/international settings (Patel 2009). Given this, we developed indicators, variables, and parameters based on the definition of food sovereignty from the Declaration of combined with insights from Lang and Heasman's Ecologically Integrated Paradigm. According to Nyéléni, there are six pillars of food sovereignty, namely, that food sovereignty: (1) focuses on food for the people, (2) values food providers, (3) localizes food systems, (4) puts control locally, (5) builds knowledge and skills, and (6) works with nature. As such, local markets,

[1] This is not to say that the food security definition, or its operationalization for policy, is not without its problems and critics. See, for instance, Lappé et al. (2013) on weaknesses in the FAOs methodology for defining and counting hunger.

agro-ecology, and farmer/pastoralist/fisher-led production, distribution, and consumption are key to food sovereignty discourse and practice. Similarly, Lang and Heasman's EIP—with which food sovereignty is associated—takes a "whole-chain systems approach" (p. 40), including localized and decentralized food systems and economies, which rely on farmer-knowledge and environmentally friendly production methods to promote dietary diversity and human and ecosystem health.

Based on the above, we defined three food sovereignty indicators. First, for *food system sustainability*, we measured motivations and practices in homegardens and on farms, scored in relation to Nyéléni and the EIP. Because health is central, especially in Lang and Heasman, we defined a *food consumption habits* indicator to assess what people were eating, and how they were preparing their meals. As industrial food products are those in which most decisions are made and most value is added off-farm, we proposed that high rates of instant food consumption in the household is less associated with food sovereignty and the Ecologically Integrated Paradigm. We also included a *food expenditure* indicator, based on previous studies that illustrate the positive relationship between farm-level commercialization and marketized food expenditures (e.g., Pingali 1997.).

Populating both indicator schemes with insights from Lang and Heasman's paradigms helps to move beyond the food security–food sovereignty impasse that exists in much of the literature, and proposes the two as mutually exclusive (Clapp 2014; Jarosz 2014). We do not, for instance, consider *food security* as simply a discursive and political expression of the Productionist Paradigm, just as we do not understand *food sovereignty* as the only Ecologically Integrated Paradigm. Rather, we were concerned to start to study the intersections between and among these four concepts, related especially to the lived experiences of poor, smallholder households.

To estimate the relationship between homegarden commercialization and food security and food sovereignty, we calculated overall scores from the variables in Appendix A. Scores for both food security and food sovereignty were obtained by summing the scores of each component of the three indicators. Each indicator had a maximum score of 100, so that the maximum score for food security was 400 (maximum of 100 each for availability, accessibility, utilization, and stability), and 300 for food sovereignty (maximum 100 each for food system sustainability, food habit, and food expenditure). Indicators of food security and food sovereignty were assumed to have equal weight. For indicators with more than one variable, the weighting was adjusted to the number of variables. The conceptual model is shown in Fig. 2.

Beyond food security and food sovereignty indicators that we were used for quantitative analysis, respondents raised

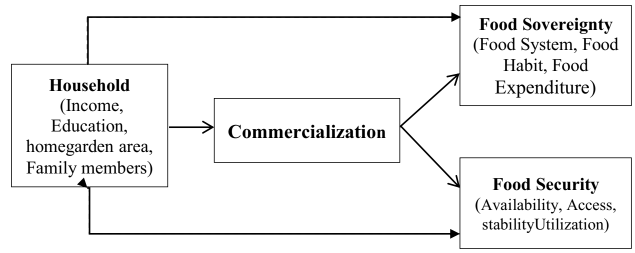

Fig. 2 Analytical framework for studying homegarden commercialization

important issues that did not fit with our standard questionnaire. For instance, political support and policy framework characteristics emerged as issues that needed to be discussed further and independently of the survey. Also, we needed to ask follow-up questions to some survey items to deepen our understanding of motivations for, and effects of, commercialization. Therefore, we also used in-depth interviews with 12 households as mentioned above to enhance the analysis. Findings from interviews are included in the results section.

Quantitative data analysis

To access the relationships between variables in this research, we translated the conceptual framework in Fig. 2 into the following empirical models:

$$Co = \gamma_{Co1} inc + \gamma_{Co2} edu + \gamma_{Co3} area + \gamma_{Co4} fsize + \varepsilon_{Co},$$
$$Sy = \gamma_{Sy1} inc + \gamma_{Sy2} edu + \gamma_{Sy3} area + \gamma_{Sy4} fsize + \beta_{Sy} Co + \varepsilon_{Sy},$$
$$Ha = \gamma_{Ha1} inc + \gamma_{Ha2} edu + \gamma_{Ha3} area + \gamma_{Ha4} fsize + \beta_{Ha} Co + \varepsilon_{Ha},$$
$$Ex = \gamma_{Ex1} inc + \gamma_{Ex2} edu + \gamma_{Ex3} area + \gamma_{Ex4} fsize + \beta_{Ex} Co + \varepsilon_{Ex},$$
$$Av = \gamma_{Av1} inc + \gamma_{Av2} edu + \gamma_{Av3} area + \gamma_{Av4} fsize + \beta_{Av} Co + \varepsilon_{Av},$$
$$Ac = \gamma_{Ac1} inc + \gamma_{Acc2} edu + \gamma_{Ac3} area + \gamma_{Ac4} fsize + \beta_{Ac} Co + \varepsilon_{Ac},$$
$$St = \gamma_{St1} inc + \gamma_{St2} edu + \gamma_{St3} area + \gamma_{St4} fsize + \beta_{St} Co + \varepsilon_{St},$$
$$Ut = \gamma_{Ut1} inc + \gamma_{Ut2} edu + \gamma_{Ut3} area + \gamma_{Ut4} fsize + \beta_{Ut} Co + \varepsilon_{Ut}.$$

Here, we define *Co* as the homegarden commercialization score, *inc* as household income, *edu* as years of schooling of household head, *area* as homegarden plot size, *fsize* as family size, *Sy* as food system score, *Ha* as food habit score, *Ex* as food expenditure, *Av* as food availability score, *Ac* as food accessibility score, *St* as food stability score, *Ut* as food utility score, and ε as an error term. βs and γs are defined as regression parameters indicating the effect of a regressor on a regressant in the models.

Observe that commercialization is endogenous in the last six regression models. Accordingly, the models form a simultaneous or structural equations model (SEM). Since applying the standard regression analysis by means of the ordinary least square on these models may result in biased regression coefficient estimates (Greene 2018), we adopted the maximum-likelihood approach under the structural equation modeling (SEM) framework. SEM can simultaneously overcome endogeneity problems with regards to simultaneity, measurement errors, as well as omitted variables and provide consistent estimates (e.g., Suparman et al. 2016; Ren et al., 2017). In the absence of measurement models, an SEM model is a simultaneous equations system which consistently can be estimated by the (full information) maximum-likelihood method (Greene 2018).

Furthermore, there are several motivations in analyzing the proposed model using the SEM framework (Joreskog and Sorbom 1996). First, the data of dependent variables availability, accessibility, and utility are binary and SEM allows binary-dependent variables in addition to numerical and ordinal data. This is possible to combine numerical, ordinal, and binary-dependent variables, since SEM can be based on a correlation data matrix. In our case, we use product–moment correlations for numerical data, tetra-choric correlations for binary data, and bi-serial correlations for numeric-binary data. Second, SEM provides estimates of indirect and total effect in addition to direct effect estimates. And finally, SEM provides overall model fit indices. The indices can be used to evaluate how well empirical data fit to the conceptual framework proposed. The analysis was done in Lisrel 8 with a 5% significance level. We present SEM specification of the empirical models in Appendix B.

Results

Homegarden commercialization

Commercialization in agriculture is the process of transforming subsistence farming into market-oriented agriculture. Agricultural produce is no longer seen as a means for merely meeting household food needs, but becomes a source of household income. Farmers are thus brought into broader markets through the sale of agricultural commodities, and by participating in markets for inputs, labor, assets, credit, and consumer goods. With commercialization, crop type and variety change to meet the needs of the market. From our interviews and previous research in the region (references removed for review), farmers and officials in the UCW expect commercialization to increase farmers' incomes in direct proportion to the area of land owned by the household and brought into market production, and in relation to fluctuations in the selling price.

The process of agricultural commercialization in the UCW kicked off in the 1990s when farmers began planting vegetable commodities on agricultural land, both small scale (homegarden) and large scale (cropland not surrounding the dwelling). All interviewees stated that at the beginning of the 1990s, homegardens were still common, and crops in the homegarden were used mostly to meet family food needs (subsistence), with some products going for sale. Over time, this pattern of semi-commercial use gave way to a higher prevalence of homegarden commercialization. From our sample of 95 households, we found that 85%, or 81 households, were using homegarden plots to grow products for market exclusively, rather than for home consumption. Specifically, 38% ($n=36$) of households had both commercialized homegarden plots and commercialized cropland, 47% ($n=45$) had only commercialized homegarden plots with no other agricultural land, and 15% of households ($n=14$) had traditional homegardens (for home consumption) in addition to commercialized crop land (Table 1).

Table 1 Respondent's land ownership and commercialization

Land owned for production	*N*	%
Traditional homegarden + commercialized crop land	14	15
Commercialized homegarden	45	47
Commercialized homegarden + commercialized crop land	36	38
Total	95	100

To measure the extent of homegarden commercialization at the household level, we calculated a "homegarden commercialization index" (HCI) based on von Braun et al. (1994, p. 11) "crop commercialization index" (CCI). To calculate the HCI, we divided the value of agricultural sales by the total agricultural production value for each commercialized household. This measure represents commercialization as a continuum ranging from total subsistence with an HCI value of zero, to fully commercialize with a value of 100. Based on our calculations, the average HCI for the 81 households in our study with commercialized homegardens was 80.56, ranging from a minimum of 60 to a maximum of 100. This figure demonstrates a high level of commercialization within households.

While homegardens in the UCW have traditionally been part of agroforesty systems, including cultivating a mixture of annual and perennial plants (Abdoellah and Marten 1986; Abdoellah et al. 2006), today, homegarden plots are either dominated by a few plant species, or have become cash crop monocultures. The dominant cash crops are spring onions (*Allium fistulosum*), carrots (*Daucus carota*), cabbage (*Brassica oleracea*), Chinese cabbage (*Brassica sinensis*), radish (*Raphanus sativus*), and Chilli pepper (*Capsicum annuum*), all of which are in high demand in urban markets. Spring onions are the main commodity in the study site, because of easy maintenance, relatively more stable prices, and higher profit yields. This reduction of diversity, and the dominance of commercial crops, is one of the reasons why the HCI index is high overall in the study site.

Table 2 Characteristics of households with commercialized homegardens ($n = 81$)

Variables	Min	Max	Mean	Std. Dev
Age of household head (years)	33	88	52.15	10.74
Family size (household members)	2	7	3.79	1.10
Education of HH head (years)	0	16	7.51	2.55
Homegarden area (m^2)	14	3,500	464.21	627.34
Crop field (non-homegarden) area (m^2)	0	12,600	1,020.37	2,107.93
Total area of agricultural land (m^2)	42	14,560	1,484.58	2,300.93
Income from homegarden (Rupiah)	25,000	3,000,000	630,674	619,050
Income from other farmland (Rupiah)	0	7,000,000	910,840	1,393,273
Income from off-farm employment (Rupiah)	0	7,700,000	1,121,728	105,1970,52
Total income (Rupiah)	1,100,000	12,900,000	2,663,242	1,814,422
Food expenditure per HH per month	600,000	2,000,000	1,186,420	276,637
Non-food expenditure per HH per month	60.000	5,000,000	508.395	694.490
Total expenditure per HH per month	800,000	6,800,000	1,694,815	854,561

The survey instrument asked respondents why they commercialized their homegardens, and why they did not. Improving agricultural productivity and generating surplus was the primary reason for those who had, which they tried to achieve using farm inputs. In fully commercialized homegardens, inputs were predominantly obtained from markets, and profit maximization became the farm household's driving objective. In the 14 households that had not commercialized homegardens, the main reason for maintaining home plots was that they preferred to commercialize other types of land, such as rice fields and mixed gardens, which are usually much larger than homegardens.

Household characteristics and commercialization

Demographic and household data from the 81 commercialized households are shown in Table 2. The average household included 3.79 members, and the average age of household head (HH) was 52.15. While some heads of household had no formal education, and educational levels were low overall, the average length of schooling was 7.51 years, equivalent to completing elementary school. Most respondent did not have formal education in farming, and from interviews, we know that most rely on practical experiences and local knowledge passed from generation to generation.

On average, homegardens were 464.21 m^2, and generated an average monthly income of IDR 630,674 (US$44.47), which was about 24% of the total average monthly income. Income generated from other on-farm activities such as production in rice fields and cashcrop gardens was on average IDR 910,840 (US$64.22). Additional income from non-farming activities such as waged work in village administration, as teachers, and as farm laborers averaged IDR 1,121,728 (US$79.09).

Average monthly food expenditures were IDR 1,186,420 (US$83.65), and food was the highest household expenditure category. The average non-food expenditure was IDR 508,395 (US$35.85), used for educational purposes, savings, or reuse as agricultural capital. These results reflect two potentially contradictory findings. On one hand, commercializing homegardens has the possibility to increase household income and welfare, potentially keeping small farmers out of poverty. On the other hand, household food expenditures might be high precisely, because households have commercialized their homegardens, and no longer produce food for daily food consumption needs.

Now, we turn to SEM results. First, we evaluated the parameters' estimates. The results do not show any implausible estimates of causal parameters or standard errors, and there were no negative variance estimates (Heywood cases). Second, we examined the overall model fit (Table 3). We used two statistical tests: the Chi-square test and the RMSEA close-fit test. The Chi-square test (line 1) showed that the proposed empirical model was not well fitted to the data, but its *p value* approached a 0.05 significance level, indicating sufficient model compatibility. The RMSEA close-fit result (line 2) confirmed this: the *p value* was 0.15, which was greater than the significance level. Accordingly, we can conclude that the model is sufficiently fitted to the data. The other two overall fit evaluations, RMR and GFI, are descriptive. Their values showed a good model fit. The RMR value is smaller than 0.05 (line 3), while the GFI value is greater

Table 3 Goodness of fit

Index	Value	Degree of freedom	*p* value
Chi^2	21.92	12	0.038
RMSEA	0.085	–	0.150
RMR	0.048	–	–
GFI	0.966	–	–

*Denote significance at the 5% levels, respectively

Table 4 SEM measurement for determinants of homegarden commercialization

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Commercialization	Education	γ_{Co1}	−0.49	0.11	−4.61	0.000	Sig										
2		Income	γ_{Co2}	0.44	0.16	2.77	0.006	Sig										
3		Land area	γ_{Co3}	0.07	0.15	0.44	0.659	Not sig										
4		Family member	γ_{Co4}	−0.15	0.09	−1.58	0.114	Not sig										

*Denote significance at the 5% levels, respectively

than 0.95 (line 4). Thus, we conclude that the model is fit to the data and we can proceed to the discussion regarding the causal parameters.

Using SEM, we tested the effect of four household characteristics (education, land area, family size, and income) on the degree of homegarden commercialization (Table 4). Education of the household head had a significant negative effect on homegarden commercialization: an increase in education of 1 standard deviation (1 SD) will decrease homegarden commercialization (HGC) by 0.49 standard deviation (SD). Household total income had a significant positive effect, with an increase of 1 SD increasing HGC by 0.44 SD. This could be due to farmers' tendency to reinvest their income in seed and inputs for growing commercial crops in the homegarden, thereby maximizing production, and changing from high to low plant species diversity. Several informants indicated that monocultural homegardens generated more income than homegardens planted with a high diversity of plants. It means that higher income households opt more for market-based homegarden production. The size of the homegarden and family size had no a significant effect on homegarden commercialization.

Commercialization and food security

Results indicate that homegarden commercialization had a significant negative effect on food security through food availability (0.91 SD decrease), utility (0.53 SD decrease), and stability (0.33 SD decrease) (Tables 5, 6, 7), and a significant positive effect on food security through food accessibility (Table 8).

The strong negative relationship between commercialization of, and availability of food from, homegardens is not surprising. By producing commercial crops in their homegardens, respondents already transformed the primary function of homegardens from fulfilling household needs, to generating more agricultural outputs for sale. Based on our interviews, homegardens have largely lost their food availability function, and respondents bought most their food from the market. In addition, the food availability is also significantly influenced by the educational level and income of the household heads through commercialization. The amount of influence from educational level of the household head and income were 0.44 and −0.40, respectively (Table 5).

Homegarden commercialization also had a significant negative effect on food utility (Table 6). While income had a significant and positive effect on food utility, its indirect effect was negative. As a result, its total effect was insignificant. We can conclude that there was no influence of income on food utility. Table 6 shows that educational level of the household head had a significant and positive indirect effect on food utility through commercialization.

Table 5 SEM Measurement for determinants of food availability

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Availability	Commercialization	β_{Av}	−0.91	0.05	−19.65	0.000	Sig										
2		Education	γ_{Av1}	0.09	0.05	1.72	0.085	Not sig	0.44	0.10	4.49	0.000	Sig	0.53	0.10	5.05	0.000	Sig
3		Income	γ_{Av2}	0.05	0.07	0.66	0.509	Not sig	−0.40	0.14	−2.74	0.006	Sig	−0.35	0.16	−2.23	0.026	Sig
4		Land area	γ_{Av3}	−0.08	0.06	−1.24	0.216	Not sig	−0.06	0.14	−0.44	0.659	Not sig	−0.14	0.15	−0.94	0.348	Not sig
5		Family member	γ_{Av4}	−0.01	0.04	−0.22	0.823	Not sig	0.13	0.09	1.57	0.116	Not sig	0.13	0.09	1.34	0.179	Not sig

*Denote significance at the 5% levels, respectively

Table 6 SEM measurement for determinants of food utility

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Utilization	Commercialization	β_{Ut}	−0.53	0.10	−5.11	0.000	Sig										
2		Education	γ_{Ut1}	0.03	0.12	0.23	0.818	Not sig	0.26	0.08	3.42	0.001	Sig	0.29	0.12	2.45	0.014	Sig
2		Income	γ_{Ut2}	0.36	0.16	2.24	0.025	Sig	−0.23	0.10	−2.42	0.015	Sig	0.13	0.17	0.73	0.468	Not sig
3		Land area	γ_{Ut3}	−0.15	0.15	−1.05	0.294	Not sig	−0.04	0.08	−0.44	0.660	Not sig	−0.19	0.17	−1.14	0.255	Not sig
4		Family member	γ_{Ut4}	−0.05	0.09	−0.54	0.589	Not sig	0.08	0.05	1.51	0.132	Not sig	0.03	0.10	0.28	0.780	Not sig

*Denote significance at the 5% levels, respectively

Table 7 SEM measurement for determinants of food stability

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Stability	Commercialization	β_{St}	−0.33	0.12	−2.83	0.005	Sig										
2		Education	γ_{St1}	−0.01	0.13	−0.05	0.963	Not sig	0.16	0.07	2.41	0.016	Sig	0.15	0.12	1.29	0.196	Not sig
2		Income	γ_{St2}	0.23	0.18	1.27	0.203	Not sig	−0.14	0.07	−1.97	0.049	Sig	0.08	0.18	0.47	0.637	Not sig
3		Land area	γ_{St3}	−0.03	0.16	−0.17	0.865	Not sig	−0.02	0.05	−0.44	0.663	Not sig	−0.05	0.17	−0.29	0.770	Not sig
4		Family member	γ_{St4}	0.07	0.10	0.72	0.470	Not sig	0.05	0.04	1.38	0.168	Not sig	0.12	0.11	1.16	0.246	Not sig

*Denote significance at the 5% levels, respectively

Table 8 SEM measurement for determinants of food accessibility

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Accessibility	Commercialization	β_{Ac}	0.50	0.10	5.05	0.000	Sig										
2		Education	γ_{Ac1}	0.24	0.11	2.25	0.025	Sig	−0.24	0.07	−3.40	0.001	Sig	0.00	0.11	0.01	0.992	Not sig
3		Income	γ_{Ac2}	−0.23	0.15	−1.54	0.124	Not sig	0.22	0.09	2.43	0.015	Sig	−0.02	0.16	−0.09	0.925	Not sig
4		Land area	γ_{Ac3}	−0.31	0.14	−2.24	0.025	Sig	0.03	0.07	0.44	0.660	Not sig	−0.28	0.16	−1.77	0.077	Not sig
5		Family member	γ_{Ac4}	−0.18	0.09	−2.09	0.036	Sig	−0.07	0.05	−1.51	0.132	Not sig	−0.25	0.10	−2.63	0.009	Sig

*Denote significance at the 5% levels, respectively

Homegarden commercialization had a significant negative effect on food stability, which we defined in terms of sustainable farming practices (Table 7). Education had a significant and positive effect on food stability (0.16 SD increase), and income a significant negative effect (0.14 SD decrease) (Table 7). Under commercialization, farmers remake homegardens as market spaces oriented to high productivity, typically increasing their use of agrochemicals. The homegarden becomes just another source of income, losing its nutritional function, while contributing further to soil and water pollution through expanded pesticide and synthetic fertilizer use. In contrast, results from SEM analysis revealed that the commercialization of homegarden did significantly and positively affect food accessibility (0.50 SD increase) (Table 8). The strong relationship between commercialization of, and food accessibility from, homegardens is very understandable due to the loss of homegardens as sources of local food. Respondents become more concerned with cheap prices and large quantities of food, rather than quality, hygiene, and nutritional status.

The size of homegarden and family size had significant negative effects on food accessibility, and income through commercialization had a significant positive effect on food accessibility (Table 8). Food accessibility is also positively influenced by educational level of household heads. In contrast, the indirect effect of educational level on food accessibility through commercialization was negative. As a consequence, the total effect of educational level food accessibility was insignificantly different from zero (Table 8).

Commercialization and food sovereignty

Using the same method described in Sect. "Commercialization and food sovereignty", we tested the effect of homegarden commercialization on household food sovereignty, using score from our food sovereignty indicators, i.e., food system sustainability; food expenditure; and food habit. Commercialization of homegardens had significant effects on food system sustainability and food expenditure, but not the food habit indicator (Tables 9, 10, 11). There was a moderate influence of commercialization of homegardens to food system sustainability (0.39 SD decrease). Education had a significant positive indirect effect on food system sustainability through commercialization (0.19 SD increase). In contrast, income had a significant negative indirect effect on food system sustainability through commercialization (0.17 SD decrease) (Table 9).

Commercialization of homegardens and income (of the household also had significant and positive effect on household food expenditure (0.24 SD increase and 0.53 SD increase, respectively) (Table 11). Through commercialization, education had a significant negative indirect effect on food expenditure (0.12 SD decrease) (Table 11). Based

Table 9 SEM measurement for determinants of food system

No	Variable			Direct effect					Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Food system	Commercialization	β_{Sy}	−0.39	0.11	−3.37	0.001	Sig										
		Education	γ_{Sy1}	−0.04	0.13	−0.31	0.760	Not sig	0.19	0.07	2.72	0.007	Sig	0.15	0.12	1.25	0.210	Not sig
		Income	γ_{Sy2}	0.31	0.18	1.78	0.076	Not sig	−0.17	0.08	−2.13	0.033	Sig	0.14	0.18	0.80	0.421	Not sig
		Land Area	γ_{Sy3}	−0.10	0.16	−0.63	0.526	Not sig	−0.03	0.06	−0.44	0.661	Not sig	−0.13	0.17	−0.75	0.454	Not sig
		Family member	γ_{Sy4}	−0.02	0.10	−0.19	0.853	Not sig	0.06	0.04	1.43	0.153	Not sig	0.04	0.11	0.36	0.718	Not sig

*Denote significance at the 5% levels, respectively

Table 10 SEM measurement for determinants of food habit

No	Variable		Direct effect						Indirect effect					Total effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z Value	p Value	Sign	Estimate	Standard deviation	z Value	p Value	Sign	Estimate	Standard deviation	z Value	p Value	Sign
1	Food habit	Commercialization	β_{Ha}	−0.19	0.12	−1.62	0.105	Not sig										
		Education	γ_{Ha1}	−0.05	0.13	−0.35	0.726	Not sig	0.09	0.06	1.53	0.127	Not sig	0.05	0.12	0.40	0.686	Not sig
		Income	γ_{Ha2}	−0.14	0.18	−0.74	0.461	Not sig	−0.08	0.06	−1.40	0.162	Not sig	−0.22	0.18	−1.23	0.217	Not sig
		Land area	γ_{Ha3}	0.06	0.17	0.37	0.712	Not sig	−0.01	0.03	−0.43	0.670	Not sig	0.05	0.17	0.29	0.773	Not sig
		Family member	γ_{Ha4}	−0.05	0.11	−0.44	0.664	Not sig	0.03	0.03	1.13	0.258	Not sig	−0.02	0.11	−0.16	0.869	Not sig

*Denote significance at the 5% levels, respectively

Table 11 SEM measurement for determinants of food expenditure

No	Variable	Direct effect							Indirect effect					Total Effect				
	Dependent	Independent	Parameter	Estimate	Standard deviation	z value	p value	Sign	Estimate	Standard deviation	z value	P value	Sign	Estimate	Standard deviation	z value	p value	Sign
1	Food expenditure	Commercialization	β_{Ex}	0.24	0.10	2.36	0.018	Sig										
2		Education	γ_{Ex1}	0.05	0.11	0.41	0.680	Not sig	−0.12	0.06	−2.10	0.036	Sig	−0.07	0.10	−0.69	0.493	Not sig
3		Income	γ_{Ex2}	0.53	0.16	3.38	0.001	Sig	0.10	0.06	1.80	0.071	Not sig	0.63	0.15	4.10	0.000	Sig
4		Land area	γ_{Ex3}	−0.12	0.14	−0.87	0.386	Not sig	0.02	0.04	0.43	0.665	Not sig	−0.11	0.15	−0.73	0.463	Not sig
5		Family member	γ_{Ex4}	0.10	0.09	1.10	0.272	Not sig	−0.04	0.03	−1.31	0.190	Not sig	0.06	0.09	0.69	0.489	Not sig

*Denote significance at the 5% levels, respectively

on interviews, informants are no longer interested in growing a high diversity of plants in their homegardens to fulfill daily food needs. They preferred to grow cash crops in their homegardens to be sold in the market, and to buy food from local markets. They were aware of becoming dependent on the market system, but for them, the potential economic benefits of planting cash crops in homegardens outweighed the potential risks of market dependence. Furthermore, several informants said that the costs of production were not very risky, so the economic benefits from cash cropping homegardens become the main motivation for commercialization.

Discussion

Our study shows that small-scale farmers in the Upper Citarum Watershed are transforming their homegardens from subsistence to commercial production. Profit maximization has become the driving objective for small-scale farming households, and as a result, cash crops that are in high demand in urban markets—especially spring onion, carrots, cabbage, and radish—have become dominant, not only on farmland, but also in homegardens. As Abdoellah et al. (2006) have shown, changing the species composition of the homegarden also changes the structure and function of the homegarden. The small plots adjacent to houses that once grew vegetables and fruits for home consumption have become incorporated into commodity production, cutting off their self-consumption function and compelling households to buy more food from outside: this requires more income, plays a role in shifting dietary patterns to more instant foods, and contributes to the monoculture-ization of the UCW.

Household characteristics and commercialization

Of the household factors which we examined, the level of education of household heads and income were the most important determinants of homegarden commercialization. Education level had a significant negative effect on homegarden commercialization, since household heads with higher levels of education have more options for earning income—including generating income from rice fields and cash crop gardens knowns as “kebun sayur”—and do not have to rely solely on their homegardens, which they use primarily for home consumption. In some cases, they used their gardens as a “nursery” for crops like green onion, tomatoes, and cabbages. In contrast, household heads with lower levels of education had no option to obtain income from other sources, so they maximize their homegardens as an income source.

Income had a significant positive effect on homegarden commercialization. Because selling crops from the homegarden has the possibility to increase household income and welfare—potentially keeping small farmers out of poverty—farmers tend to reinvest their income in seed and inputs for growing commercial crops in the homegarden, thereby maximizing production, and changing from high to low plant species diversity. However, on the other hand, commercialized homegardens no longer produce food for daily consumption needs. Indeed, of the households in our study who had only homegarden plots for production, all had commercialized these spaces. This finding is related to Abdoellah et al.’s (2006) argument that small-scale farmers who do not have access to agricultural land are more likely to commercialize their homegardens, regardless of its size. It also reflects the development situation in poor rural areas, where people are pressed to use whatever land is at their disposal for income-generating activities.

Homegarden commercialization effects on food security

Using indicators developed for this study, our analysis showed that homegarden commercialization negatively affected household food security through food availability, utility, and stability indicators. In other words, commercialization does not always have a positive effect on the condition of the household. First, we found a negative relationship between commercialization and food availability. In the most basic sense, there is less food available to households as they turn their homegardens into commercial commodity plots. While this is an evident statement, our findings contribute to the growing body of literature, showing that small-scale farmers are unable to fulfill their daily food needs from household and farming operations (e.g., Gray et al. 2014; Mattsson et al. 2017). In the commercialization era, farmers do not view the homegarden as a source a food availability at the household level anymore.

Homegarden commercialization significantly and negatively affected food utilization too, as we defined these categories in our indicator scheme. In terms of utilization, which we defined in terms of perceptions of food quality versus food quantity, our results indicated that commercialization does not replace the former with the latter. Our current study did not, however, analyze what respondents defined as “quality food.” From previous research, we know that as small-holder farmers commercialize their homegardens, they eat less traditional vegetables with high nutritional value and less home-produced meat (Abdoellah et al. 2006). The health implications of switching to marketed foods, including processed foods, have not yet been studied in the UCW.

Homegarden commercialization had also a significant negative relationship with the food stability variable. The importance of environmentally friendly farming and of ecologically informed knowledge seems to be declining and changing in the era of commercialization. With commercialization, the homegarden becomes just another source of income, losing its other functions as mentioned several authors (Abdoellah and Marten 1986; Kumar and Nair 2004; Nair and Garrity 2012; Galhena et al. 2013; and Mattsson et al. 2017). This tends to contrast with the concept of food security as defined by the FAO, which includes considerations for environmentally responsible for management practices. Our results-combined with interview data—show that farmers attitudes have changed, and they do not consider using environmentally sustainable production methods as important.

Finally, in term of food accessibility, people in the study villages could easily meet their daily food needs through markets. Shops that sell food were abundant in the study site, spread evenly in every hamlet (*dusun/kampung*), and even in the smallest administrative units of neighbourhood associations (*rukun tetangga*). Easy access was also supported by good road conditions connecting people to bigger, more urban markets if necessary. Food accessibility, of course, also depend on the household's ability to buy food—and what kind of food—based on income and price (FAO 2008). Previous research in the UCW has shown that focusing on a narrow range of cash crops has resulted in only short-term improvements in farmers' incomes. The high productivity required to maintain this improvement is often difficult to sustain, especially since cash crops also require higher energy and higher cost inputs in the form of fertilizers and pesticides (Abdoellah et al. 2006). Further longitudinal research is needed (1) to examine the extent to which income increases resulting from commercialization are sustainable, (2) to assess the extent to which households have become dependent on the market, and (3) to evaluate the nutritional contribution of the kinds of food that marginally (and often temporarily) increased incomes allows a household to purchase.

Homegarden commercialization effects on food sovereignty

The first thing to say about homegarden commercialization and food sovereignty is that there is no food sovereignty movement to speak of in the UCW. Furthermore, farmers do not use the narrative of food sovereignty, nor do they demand control over their food system, as in food sovereignty discourse. Still, because the tenants of food sovereignty are increasingly recognized as important parts of food and agricultural sustainability, and because Lang and Heasman (2016) associated food sovereignty with their Ecologically Integrated Paradigm, we found it important to study.

Based on our indicator framework, we found an overall significant negative relationship between homegarden commercialization and food sovereignty, and for the *food system sustainability* and *food expenditure* indicators specifically. On the first finding, commercialization is shifting the UCW from local food systems to increased distance food chains. Again, findings illustrate less production for self-consumption, more production *for* markets, and more consumption *from* markets. These realities shift the locus of the food system—and opportunities for its control—from local households to the market, which may be regionally, nationally, or globally based and operated. Farmers in the UCW are using more chemical fertilizers to produce a narrow range of crops grown in monoculture. Not only does this shift have well-known environmental implications, it also means that that farmers are neither using nor learning skills of farming "with nature," as in agro-ecology or other forms of sustainable production.

Our findings also demonstrated that household *food expenditure* increased with homegarden commercialization. Surely, household food expenditures increase with the level of commercialization since spices, vegetables, and other foodstuffs must be purchased from the market. This situation is a departure from the past, when homegardens provided additional income and nutrition, especially during *paceklik* seasons (famine) when food was scarce. With commercialization, contributions of carbohydrates, protein, vitamins, and minerals from the homegarden are lost (see Abdoellah and Marten 1986; Mohri et.al 2013; Mattsson et.al 2017).

Our analysis did not find a significant relationship between commercialization and *food consumption habits*, as we defined them for the study. Although insignificant, the relationship was negative, and insights from interviews suggest that there has been a change in household food habits: importantly, most informants indicated that they often eat instant foods such as instant noodles and instant cooking spices. Informants indicated the main reasons for this shift as practicality, convenience, and increasingly "fastfood-based" lifestyles. Therefore, instant food products and instant spices dominated the household kitchen. Instant noodles, for example, have emerged as a substitute for rice, and in some cases, are used as a dish on their own. The negative health impacts of instant noodles, which are high in sodium and low in nutritional value, are well known (e.g., Lee et al. 2009).

Other effects of homegarden commercialization

In addition to testing commercialization effects on food security and food sovereignty, in our observations and in-depth interviews with key informants, we found other areas of effect for qualitative discussion. First, in the context of commercialization and the need for higher outputs and income, villagers are increasingly becoming indebted to middleman and moneylenders. Debt has the potential to lead to future changes in land ownership and management decisions (Gerber 2014), which will challenge the continued existence of somewhat autonomous homegardens even more. This insight reflects Michon and Mary's (1994) finding that apart from high population density, major factors that threatened the existence of homegardens in West Java were the increased scarcity of agricultural land, conflict between commercial agriculture and traditional food production systems, and development of a market economy.

Second, we found that commercialization has also weakened institutional systems of farmer support that were previously common in the area. This is further evidenced by the absence of *Gapoktan* (cooperative farmers' groups) in the study village. The loss of these groups seems likely to effects small-holders' collective market power, their knowledge and training on new systems and innovations, and their income. Further studies on these effects are needed.

Conclusion

This study found that homegarden commercialization is proceeding rapidly in the Upper Citarum Watershed in West Java, Indonesia. Despite the promise of commercialization improving small-holder farmers' lives and livelihoods, our quantitative analysis revealed negative effects on household food security and food sovereignty, based on the indicators, we defined for the research. Given the long history of homegardens' contribution to daily food needs in Indonesia and elsewhere, we propose that they should be supported to serve as islands of fresh and nutritionally rich foods, in a sea of otherwise highly processed and nutritionally poor food products. Furthermore, practices in homegardens that reduce fertilizer and pesticide use also play a role in decreasing pollution and environmental degradation. As such, homegardens should be included in health, food security, agriculture, environmental, and rural development policies, coming out of various ministries and administrative bodies. Furthermore, to help curb the rush to commercialize every last bit of land, especially in poor rural areas, a 'Homegarden Reserve' subsidy and education program should be initiated to support farmers to maintain—or recover—their home plots for ecological, agro-ecological, and/or agro-forestry production. As policy makers in Indonesia consider further reforms of food and development policy—including the focus in recent documents on both food security and food sovereignty (see Rafani 2014)—homegardens should be included and supported. Similarly, in other developing and developed countries, the household contributions of homegardens should be further investigated, and included in intersectional policy.

One upside to this story is that land taken out of homegardening can be put back into it, provided that households have not become excessively burdened by debt. By supporting ecological practices, and reducing the use of agrochemicals on these small, but widely distributed plots, homegardens have the potential to play a role not only in food security and food sovereignty, but also in addressing pollution. These, all, are pressing tasks in Indonesia and more broadly.

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Appendix A

See Tables 12 and 13.

Table 12 Food Security indicators [a], variables [b], parameters, and scoring rubrics

Indicator	Variable	Parameter	Score	Values
Availability	Availability of food for self-consumption from homegarden	Food available from homegarden	0–100	Percentage of food available from homegarden (%)
Access	Consideration in buying food outside the home	0 = Price and quantity 1 = Buy from local sources	0 = 0; 1 = 100	0 = does not support food security 1 = supports Food Security
Utilization	Food quality perception	0 = Quantity and price 1 = Quality and hygiene	0 = 0; 1 = 100	0 = does not support food security 1 = supports food security
Stability	Environmental awareness in land management	0 = No consideration for environment 1 = Consideration for environment	0 = 0; 1 = 50	0 = does not support food security 1 = supports food security
	Kind of knowledge used to cultivate homegardens	0 = Industrial agriculture 1 = Local knowledge	0 = 0; 1 = 50	

Table 13 Food Sovereignty indicators [a], variables [b], parameters, and scoring rubrics

Indicator	Variable	Parameter	Score	Values
Food system sustainability	Motivation to cultivate homegarden land (pillars 2,3,4)	0 = Market oriented (for sale) 1 = For family needs	0 = 0; 1 = 12,5	0 = does not support Food Sovereignty 1 = supports Food Sovereignty
	Types of crops in homegarden (pillars 5,6)	0 = Monoculture 1 = Polyculture	0 = 0; 1 = 12,5	
	Considerations in choosing crop type (pillars 1,3,4)	0 = Quantity and market oriented 1 = Quality and for subsistence	0 = 0; 1 = 12,5	
	Type of fertilizer commonly used for farming activities (pillars 5,6)	0 = Chemical 1 = Organic	0 = 0; 1 = 12,5	
	Type of seed commonly used for farming activities (pillars 4,5,6)	0 = Genetically modified 1 = Local seed	0 = 0; 1 = 12,5	
	Sales of crop products (pillars 2,3,4)	0 = Own sale to market 1 = Through traders	0 = 0; 1 = 12,5	
	Land ownership (pillars 2,3,4)	0 = Land rent 1 = Land owner	0 = 0; 1 = 12,5	
	Food expenditure (pillar 1)	0 = > 50% income for food 1 = < 50% income for food	0 = 0; 1 = 12,5	
Food consumption habits	Staple food consumption (pillar 1)	0 = < 3x/day 1 = ≥ 3x/day	0 = 0; 1 = 25	0 = does not support Food Sovereignty 1 = supports Food Sovereignty
	Processed food consumption (pillars 1,3,4)	0 = > 2x/week 1 = 1x/week	0 = 0; 1 = 25	
	Food cooking methods (pillar 1)	0 = Fried 1 = Boiled	0 = 0; 1 = 25	
	Spices commonly used for cooking activities (pillars 1,3)	0 = Instant spices 1 = Natural spices	0 = 0; 1 = 25	
Food expenditures	Food expenditure/month/capita (pillars 1,4)	0 = Food expenditure/month > 60% of total expenditure 1 = Food expenditure < 60% total expenditure	0 = 0; 1 = 100	0 = does not support Food Sovereignty 1 = supports Food Sovereignty

[a]Indicators are based on statements in the Forum for Food Sovereignty's (2007) Nyéléni Declaration, insights from Lang and Heasman's (2016) Ecologically Integrated Paradigm, and academic work (e.g., Patel 2009)

[b]Variables were defined based on the food sovereignty "pillars" in the Nyéléni Declaration

Appendix B

Observe that the empirical models consist of observed variables only. Here, each of the constructs is indicated by a single indicator. It results in a sub-model 2 of Lisrel (i.e., causal models for directly observed variables). The SEM model reads:

$$y = \mathrm{B}y + \Gamma x + \zeta,$$

with

$$y' = \left[\, Co\ Sy\ Ha\ Ex\ Av\ Ac\ St\ Ut \,\right],\ x' = \left[\, inc\ edu\ area\ fsize \,\right]$$

$$B = \begin{bmatrix} 0 & 0\,0\,0\,0\,0\,0\,0\,0 \\ \beta_{Sy} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{Ha} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{Ex} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{Av} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{Ac} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{St} & 0\,0\,0\,0\,0\,0\,0 \\ \beta_{Ut} & 0\,0\,0\,0\,0\,0\,0 \end{bmatrix} \Gamma = \begin{bmatrix} \gamma_{Co1} & \gamma_{Co2} & \gamma_{Co3} & \gamma_{Co4} \\ \gamma_{Sy1} & \gamma_{Sy2} & \gamma_{Sy3} & \gamma_{Sy4} \\ \gamma_{Ha1} & \gamma_{Ha2} & \gamma_{Ha3} & \gamma_{Ha4} \\ \gamma_{Ex1} & \gamma_{Ex2} & \gamma_{Ex3} & \gamma_{Ex4} \\ \gamma_{Av1} & \gamma_{Av2} & \gamma_{Av3} & \gamma_{Av4} \\ \gamma_{Ac1} & \gamma_{Ac2} & \gamma_{Ac3} & \gamma_{Ac4} \\ \gamma_{St1} & \gamma_{St2} & \gamma_{St3} & \gamma_{St4} \\ \gamma_{Ut1} & \gamma_{Ut2} & \gamma_{Ut3} & \gamma_{Ut4} \end{bmatrix}$$

$\Psi = diag\left[\mathrm{var}(\varepsilon_{Co})\ \ \mathrm{var}(\varepsilon_{Sy})\ \ \mathrm{var}(\varepsilon_{Ha})\ \ \mathrm{var}(\varepsilon_{Ex})\ \ \mathrm{var}(\varepsilon_{Av})\ \ \mathrm{var}(\varepsilon_{Ac})\ \ \mathrm{var}(\varepsilon_{St})\ \ \mathrm{var}(\varepsilon_{Ut})\right]$ and

$$\Phi = \begin{bmatrix} \mathrm{var}(inc) & & & \\ \mathrm{cov}(edu, inc) & \mathrm{var}(edu) & & \\ \mathrm{cov}(area, inc) & \mathrm{cov}(area, edu) & \mathrm{var}(area) & \\ \mathrm{cov}(fsize, inc) & \mathrm{cov}(fsize, edu) & \mathrm{cov}(fsize, area) & \mathrm{var}(area) \end{bmatrix}.$$

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