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Review

Drivers of Households' Land-Use Decisions: A Critical Review of Micro-Level Studies in Tropical Regions

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Abstract: This paper reviews 91 recent empirical and theoretical studies that analyzed land-use change at the farm-household level. The review builds on a conceptual framework of land-use change drivers and conducts a meta-analysis. Results show that the conversion of forests into cultivated land or grassland, mainly used for agriculture or ranching, are most frequently analyzed. Only a small number of studies consider the transition of wetlands for agriculture and few cases deal with the conversion from agriculture into protected zones. Moreover, interactions between drivers add to the complexity of land-use change processes. These interrelationships are conditioned by institutions and policies. In particular, the market-oriented reforms adopted by many developing countries in the 1980s and 1990s seem to have had an important role in altering land use, while impacts of more recent policies need to be better explored. Many studies rely on small samples and face problems of internal validity. Despite these weaknesses, the literature points at micro-level economic growth, for example in income and capital endowments, as a strong catalyst of human induced land-use change. However, the review suggests that—across the different studies and cases—there is considerable heterogeneity in the relationship between these factors and land-use change.

Keywords: land-use change; farm households; deforestation; meta-analysis; micro-level

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1. Introduction

Global change is the aggregate result of billions of individual decisions and understanding the determinants of these decisions is crucial for its analysis. This is particularly true in the case of land-use change as one important component of global change. Land-use change has impacts on biodiversity, food security as well as on the levels of greenhouse gas (GHG) emissions. Governments, policies as well as global and domestic markets set the conditions, under which micro-agents, i.e., households, firms, and farms, eventually take and implement decisions on land use. This process is accelerated by interlinked and interacting economic systems as well as the digital proximity of social systems in a globalizing world [1–3].

Studying the causes and consequences of land-use change requires the integration of natural sciences with social and geographical information [4]. Geographers and natural scientists utilize spatially explicit models at highly disaggregate scales while social scientists mostly rely on models that include human behavioral components to understand the determinants of land-use change [5]. Based on these approaches, land system science (LSS) has evolved from a science that solely addressed the patterns and causes of deforestation to a science that is now capable of analyzing subtler land-cover changes through the use of intricate models that conceptualize the causal and feedback relationships within coupled human and environmental dynamics [6,7]. The data fed into these models has become more sophisticated in recent years and now includes high-resolution satellite imagery, geographic information systems as well as detailed socio-economic and geophysical data that model the human-environment interactions driving land-use change [8]. Given the theory of coupled human and environmental systems, land system science extends its scope to the linkages and feedback mechanism between integrated coupled systems over geographically and socially large distances [2,3]. These so-called telecoupled interactions include socioeconomic and environmental effects, which might be non-linear and multidirectional and lead to intended or unintended, direct and/or indirect changes of different orders in the affected system [3].

Since the emergence of land-change science, a number of literature reviews and meta-analyses that analyze the causes of land-use change have been published, in particular Angelsen and Kaimowitz [9] and Geist and Lambin [10]. These reviews are based on the first wave of land-use change studies that analyzed the causes of deforestation in tropical regions in the early 1990's. These literature reviews called for more micro-level case studies that enable a better understanding of the causes and the mechanisms of land-use change [9,10]. Since then, a large empirical literature of micro studies has emerged and meta-analyses of these studies are included in Keys and McConell [11] and Rudel [12].

This paper aims to analyze and review the land-use change drivers that influence households' land-use change decisions. For this, we systematically review 91 micro-level studies and conduct a meta-analysis to understand the importance of specific determinants of households' land-use decisions. Similar to Keys and McConell [11], our focus is on tropical regions as they have experienced dramatic land-use change in the last decades. Hence, the studies that consist of both empirical and theoretical multidisciplinary works were conducted in tropical regions and published between the years 2000 and 2015. The studies must analyze land-use change at the village- or household level and the drivers of change have to include household characteristics. Two important contributions of our review stand out: first, we depart from the conventional practice in earlier reviews to focus on the conversion of forest lands by including a discussion on the conversion of agricultural/ranching lands, protected forests and wetlands. Secondly, by placing an emphasis on the micro-level studies, we can provide a more detailed assessment of household-level drivers than earlier reviews (with Keys and McConell [11] being the exception) that stressed the role of more aggregate drivers such as population growth and market developments. This allows us to demonstrate not only the importance of household factors for land-use change, but also the heterogeneity in the relationship between land-use change and growth-associated micro-level drivers, which is caused by the complex interactions among these drivers, in particular income and technology, and the role of context-conditions, in particular institutions, policies, and market conditions. These results imply that land-use policies will have to take into account this heterogeneity and avoid one-size fits all approaches. In fact, this may explain why global fairly uniform approaches targeted at influencing land use change, for example Reducing Emissions from Deforestation and Degradation (REDD, and REDD+) have not been overly successful [13]. The remainder of this paper is structured as follows: We first introduce a conceptual framework adapted from Angelsen and Kaimowitz' model [9]. This is followed by a systematic meta-analysis of the micro-level studies reviewed. We then provide a detailed and comprehensive literature review and close with a summary, conclusions, and some reflections on future research.

2. Conceptual Framework of Land-Use Change

To conceptualize the multiform and complex dynamics of human-environmental systems and land-use change, we build on a concept of the causes of deforestation proposed by Angelsen and Kaimowitz [9]. This simple framework that provides a stepwise distinction of the causes of deforestation has been widely cited in the both deforestation and land use literature (see for instance, Geist and Lambin [10]). It includes a three-stage-process of underlying causes (macroeconomic variables), immediate causes (decision parameters) and sources of deforestation (agents' actions).

While we find that this model is a good starting point for a more detailed analysis of the drivers of land-use change, we identify two major limitations of the framework. First, it neglects the role played by household endowments and characteristics in driving land-use change. Second, it does not explicitly consider interlinkages and feedback mechanisms within coupled human and environmental systems and between different systems. Within a system, there could be feedback mechanisms between the different stages, for example between agents' choices and underlying causes of deforestation. For instance, agents may influence policies, which again affect land-use decisions. Further, interlinkages between the decision parameters are need consideration. For example, technology and infrastructure are likely to be linked. Further, there could be multidirectional interactions of one system towards other socially and geographically remote human- environmental systems, so-called telecoupling interactions [2,3].

We draw on the framework by Angelsen and Kaimowitz [9] but modify it to suit our purposes in the following ways. First, rather than analyzing all actors of land-use change we only focus on the land-use decision parameters of farm-households and small-scale farms. Second, deforestation is obviously only one form of land-use change and we include other categories, such as reforestation or the conversion of wetlands to agriculture. Third, we expand the range of micro-level drivers (institutions, infrastructure, markets and technology) to include household characteristics and endowments (for instance, physical capital and family workforce) and key policies (for example, forest conservation policies, institutional reforms of land rights, or agricultural policies). Forth, we present more precise elaborations of the feedback mechanisms between and within the hierarchical components of land-use change within a specific human-environmental system. Fifth, we link the dynamics of one system to others capturing the potential interacting and feedback processes between two or more systems (see Figure 1). Our concept thus integrates the determinants and outcomes of land-use change in a human-environment system both vertically, i.e., between underlying causes, micro-level drivers and outcomes, as well as horizontally, i.e., between specific micro-level drivers. Embedded in a telecoupled world, it is further linked to at least one other but distant land systems by telecoupling interactions and feedbacks.

Figure 1 shows our framework. It illustrates the decision-making process of micro-level agents and how the underlying causes of land-use change (macro-economic variables) are linked to the micro-level drivers and to the final land-use change outcomes, which we define as non-used forest, forestry, protected forest, logging, fallow, agroforestry, agriculture, ranching, or wetland cultivation. Underlying causes include policies, population growth, and global markets. It further sets the dynamics of land-use change in one system in the context of telecoupling processes with other human-environmental systems. To keep it simple, we do not illustrate the potential and/or cross-scale links between specific elements of the system A to elements of the system B (and possibly further systems, which are described by the third white arrow).

Focusing on the land-use change dynamics of micro-level agents, we refer to the central causalities between macro-economic variables and micro-level drivers of land-use change. The impact of underlying policies on land-use decision making is dependent on two relevant aspects: first, on the institutional framework of land-use rights and the (non-)existence of land tenure security and second, on key policies for land use. Individual land-use decisions highly depend on the respective land governance and on the ways in which land-use rights can be transmitted and guaranteed. Likewise, land-specific key policies such as settlement programs, public schemes for highway expansion, or land extension services, influence and alter all other land-use decision parameters of agents. To illustrate how population growth affects agents' land-use decision, our concept focalizes primarily on local population pressure via immigration. Immigration is either triggered by key polices and/or by price signals of developing markets. Finally, we include the impact of global markets and focus on global cash crop markets, which create incentives for agents to switch their land use towards cash crop cultivation and thus might raise households' incomes. Income growth in turn may alter crop consumption patterns and hence crop demand on the regional and global scale.

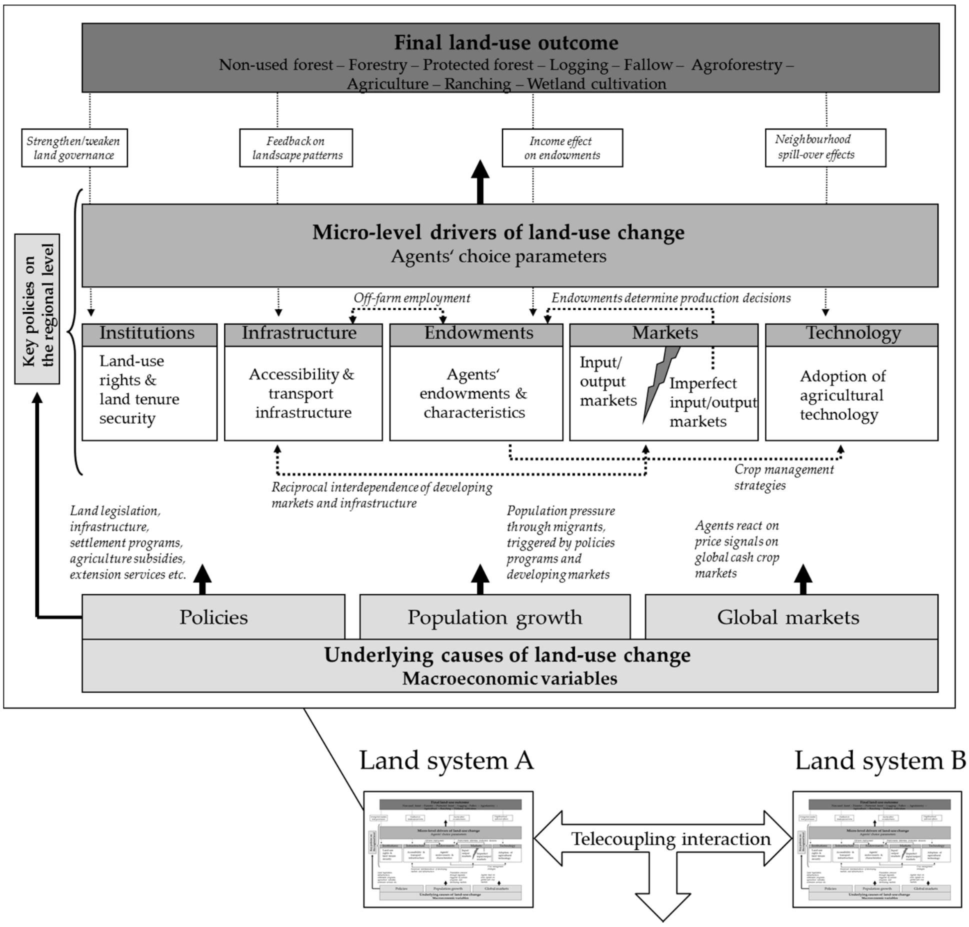

Figure 1. Concept of the micro-level drivers of land-use change. Authors' concept based on Angelsen and Kaimowitz [9], Eakin et al. [3] and Liu et al. [2].

Introducing institutions, we show that local land-use rights, such as formal property rights or informal (customary) rights drive land-use change. Taking these contrary systems as an example, agents may react differently regarding their decision on land extension or cash crop cultivation. The degree of tenure security, implemented through legal titling or local agreements, determines the reliability of these land rights. As second decision parameter, the accessibility to public services/markets centers and transport infrastructure, influences agents' land-use decisions by enabling rural households to improve their access to agricultural inputs and/or to sell their products. Thirdly, the agent's characteristics and endowments that include the culture/ethnicity of a household and for example its physical capital, labor or social capital are key parameters for agent's land-use decision making. To illustrate, a higher level of wealth enables a household to invest in a more capital intensive land use such as pasture. These individual effects are reinforced if access to capital (or other factor) markets is limited. Hence, introducing the fourth choice parameter, the quality of input and output markets plays a fundamental role for agents' land-use change. Households' land use differs if markets for labor and agricultural inputs are limited or even non-existent. For example, cash crop adoption and/or agricultural expansion—and thus the systematic forest conversion—is more restricted for households in areas with fragmented markets. Finally, land-use decisions are determined by the respective agricultural technology available for and adopted by households.

Furthermore, our framework on land-use change identifies four relationships between the micro-level drivers within one human-environmental system that are depicted by the dotted lines in Figure 1. First, there is a reciprocal link between the accessibility to infrastructure and developing markets. On the one hand, public improvements in transportation networks reduce costs and facilitate economic activity, which in turn promotes the emergence of input and output markets in remote areas. On the other hand, evolving markets trigger infrastructure development. Both dynamics are interdependent and mutually reinforcing. Second, household characteristics and endowments affect the adoption of technologies and agents' crop management strategies. For example, the adoption of a more labor-intensive technology depends on either household's capital available for hiring labor or on family workforce. Third, access to infrastructure and public services influences agents' options of off-farm employment and vice versa. Lastly, market conditions determine the production decisions of households. If input and/or output markets are limited or non-existent, households have to fall back on family workforce and capital endowments. Thus, the decision on land-use change depends on the households' own shadow price for family labor, leisure and assets and is not determined by external factor market prices.

Feedback loops also operate from the final land-use outcomes to the micro-level drivers through the mechanisms depicted by the small boxes above the micro-level drivers of land-use change. Certain land-use changes could strengthen or weaken land rights. This is especially the case if land is weakly governed and/or there are additional informal rules of land rights. Since the conversion of non-used forests in tropical regions goes along with the introduction of property rights, longer fallow periods could attract other agents to encroach and convert forestland for their own purposes. In addition, different land uses and the corresponding landscape changes may influence infrastructure requiring a different set-up such as those necessary for plantation cultivation. At the household-level, land-use choices go along with specific income effects, for example, cash constraints could be relieved allowing the household to accumulate physical capital for new investments. This in turn determines production decisions, especially so under imperfect factor markets. Finally, land-use outcomes induce neighborhood spill-over effects, for example via copying or knowledge transfer in informal networks.

Across systems, telecoupling interactions include socioeconomic-environmental effects, which might be governed and intended, for example global policy programs including the global program for sustainable forest management called Reducing Emissions from Deforestation and Degradation (REDD and REDD+). An example for unintended, ungoverned impacts across systems is the recent phenomenon of large-scale land acquisitions in developing countries – sometimes referred to as "land grabbing". These acquisitions, often by foreign investors are driven by the increased global demand for agricultural products and have repercussions, sometimes land right conflicts, in very remote places [14]. That conflicts in such places reach the attention of a worldwide audience and influence global discourses through the campaigns of NGOs shows that—in a globalized world—agents might not only cross distance but also scale and hierarchical contexts [3], thereby linking not only the elements of within but also between different systems.

3. Overview of Reviewed Studies and Meta-Analysis

Following the concepts of Cooper [15] our review adopts the elements of an *integrative research review*. As is common with integrative research reviews our study collects and compares the results of primary studies on micro-level land-use change to represent the current state-of-the-art and to point at research gaps within the relevant literature. As part of this, we apply a meta-analysis to synthesize the results of the reviewed studies systematically. Specifically, we code the qualitative information across studies according to a questionnaire (see Appendix A, Table A1). We further extend the existing theory on the micro-level drivers of land-use change and examine carefully the potential threats to validity of the reviewed studies.

The studies reviewed in this paper were collected during the period from March 2011 to September 2015. They were sourced from academic databases and search engines such as Google Scholar, Scirus, Repec, Mendeley, AgEcon Search as well as from cross references of cited papers. Key words and search items included "land-use change" and "household" or "village", restricted to studies published between 2000 and 2015.[1] Our initial search resulted in a total number of approximately 180 studies. These studies were carefully read by two of three authors and only included in the sample of studies if they met the following key criteria. First, the data analyzed in the studies must include information collected at the household or village level. In addition, the studies must analyze land-use change at the village- or household level and the drivers of change have to include household characteristics.[2] Second, the papers had to be published in peer-reviewed journals between 2000 and 2015. We took 2000 as the base year because the last comprehensive meta-analyses and empirical reviews were published in the early 2000s. Third, we restricted our sample to studies that were conducted in tropical regions as these regions experienced the highest rate of land-use change during our study period. Once papers that fulfilled all three criteria were selected, they were further screened for the methodological rigor. If the authors concluded that—despite having undergone a peer review process—a paper still failed to properly identify the drivers of land-use change at the household level it was excluded from the literature review. In the event that the same author published a set of accompanying papers using the same dataset and identifying the same drivers of land-use change, only one paper was included in the review. These restrictions resulted in a subset of 91 studies that were included in the review.

After the 91 papers were selected, the authors underwent a rigorous reading and coding process based on a questionnaire (see Appendix A, Table A1). The questionnaire was designed to collect information such as the academic backgrounds and present affiliations of the authors of the reviewed studies, the year of publication, and applied methods. The main results of the papers, i.e., the type of land-use change and land-cover change, the land-use change drivers suggested in the paper as well as the region and country of study were also systematically recorded.[3] Each paper was read and coded by two of the three authors to allow for a stringent cross-verification of all entries.

Our classification of the drivers of land-use change is based on the conceptual framework introduced in the preceding section. In addition to the five main drivers identified by Angelsen and Kaimowitz [9] we include two new drivers of land-use change, i.e., household characteristics/ endowments and key policies (see Appendix A, Table A2). Overall, 330 proxy variables for specific drivers are reported as having a significant impact on land-use change in the 91 studies.

3.1. Land-Use and -Cover Change

The literature on micro-level land-use change often defines land-use change rather implicitly or vaguely and does not use a uniform definition of land-use change. Additionally, some studies do not make a clear distinction between *land use* and *land cover*. However, to synthesize the results of the 91 studies, a precise distinction between land use and land cover is required, as suggested by Lambin and Geist [16] and Fisher and Unwin [17].

A widely used definition describes land cover as the observable (bio-) physical qualities of the Earth's land surface [18]. In contrast, classifying land use always demands a socio-economic perspective on land [17]. Consistent with this approach, Lambin and Geist [16] (p.4) refer to land use as the "purposes for which humans exploit land cover. It involves both the manner in which biophysical attributes of the land are manipulated and the intent underlying that manipulation". Hence, land use is always determined by the "arrangements, activities and inputs people undertake on a certain land-cover type to produce, change or maintain it" [18]. Following these definitions, a change in land use does not necessarily lead to a change in land cover, for example in the case of intensification. Moreover, the terms *land cover* and *land use* follow a many-to-many relation [17]. For example, land covered by *forest* could be land used for forestry or conservation. In addition, agriculture can occur

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1 Selection of articles published in peer reviewed journals and the omission of grey literature may result in a publication bias; however, we assume that acceptance for publication in a peer reviewed journal is indicative of the quality of the paper.

2 In village-level studies, these household characteristics will typically be collected at the village level, for example as the share or number of households with certain characteristics.

3 The complete list of variables coded from the reviewed studies is available from the authors upon request.

on land cover classified as grassland, woodland or wetland. Inconsistencies in the use of these terms render the systematic comparison of study results difficult, especially if evidence is based on remote sensing data, which need the interpretation of aerial information [17].

In our systematic analysis of land-use change we are able to capture subtler land-use change scenarios, which have not yet been classified in earlier literature reviews. Moreover, we illustrate that it is indeed useful and instructive to distinguish between land-cover (change) and land-use (change) clearly. We identify the initial land uses (LU) and land covers (LC) and the final LU and LC for each study in our sample using a one-to-many relationship between LC and LU categories (see Table 1). Considering the variety of research objectives and applied methodologies, we only include land uses and land covers, which are central for each study. For those cases that do not provide direct information about the initial and final land covers/ land uses, we derive the categories from study site description and central statements or conclusions provided by the respective study. Since most studies analyze several land-use change scenarios, we allow for more than one land-use change scenario per study. We finally identify 184 land-use change scenarios that fall into 33 different categories of land-use change.

Due to the variety in land-cover information across studies and disciplines (and sometimes the lack of precise information), our cover categorization follows a broader definition than other, more detailed categorizations, for example, the Land Cover Classification System (LCCS) by Di Gregorio and Jansen [18]. Thus, we classify land cover into *forest, cultivated land, grassland, shrubland, desert* and *wetland* (Table 1). Under *forest* we include land cover such as natural forest, primary forest, old-growth forest, mature forest, secondary forest, residual forest or woodland. We define *cultivated land* as areas used for agricultural purposes (including orchards and plantations). The land-cover categories *grassland, shrublands and deserts* denote land cover described as pasture land, arable land, savanna, bushland, or non-forest vegetation. Since one of the studies reviewed analyses land-use change at desert fringes, we also include desert as land cover, referring to dune landscape. The last land cover, *wetland*, indicates land covered, for example, by swamps.

Under these LC categories we further classify 12 different land uses (Table 1). We assign the following forest uses: *Non-used forest* that captures natural forests; *forestry*, which refers to resource extraction, for example, firewood collection and hunting; *protected forest* that includes forest reservation; *logging*, which denotes logged forests for commercial reasons; and *fallow*, which is land left for regeneration, mostly within a cultivation cycle of shifting cultivation. Cultivated land could be used for *agriculture* or *agroforestry* whereby agriculture as a broader term encompasses mono and mixed-cultivation (including plantations) and is mostly used for cash crop cultivation. Agroforestry describes woody perennials and agricultural crops planted in agroforestry systems as well as shifting cultivation [19,20]. Grasslands, shrublands and deserts (i.e., dune landscape) are mainly used for *ranching*; this includes livestock farming, cattle ranching or agro-pastoralism. To capture the use of natural grasslands, shrublands and deserts, we include the terms *non-used grassland/non-used shrublands/non-used deserts*. Similarly, under wetland, we subsume *non-used wetland*, that captures natural wetlands, and *wetland cultivation*, that includes landscapes, for example, with rice fields.

Overall, 77 percent of all scenarios analyzed in the reviewed studies concern land covered initially by forests (see Table 1). Within this subsample, the conversion of non-used forest and forestry receives most attention. Looking at final land uses, land is predominantly changed towards agricultural usage (52 percent) followed by ranching (22 percent) and some minor categories, like fallow (9 percent) and forestry (5 percent). Hence, as expected, the most analyzed scenario is the conversion of non-used forests or forestry for agricultural purposes, together these make up 62 cases (34 percent of all land-use changes in reviewed studies). The second largest share (35 cases or 19 percent) is accounted for by studies that analyze the conversion of non-used forests or forestry towards ranching. Hence, deforestation—represented by the land-cover change of forests into cultivated land or grassland/shrubland—is still the main focus of studies analyzing land-use change on the micro level.

Table 1. Land-use (and cover) change of reviewed micro-level case studies.

Initial LC and LU \ **Final LC and LU**		**Forest**					**Cultivated Land**		**Grassland/Shrubland/Desert**		**Wetland**		**Total**
		Non-used forest	*Forestry*	*Protected forest*	*Logging*	*Fallow*	*Agroforestry*	*Agriculture*	*Ranching*	*Non-used grassland/ shrubland/desert*	*Wetland cultivation*	*Non-used wetland*	
Forest	*Non-used forest*		6		2	1	2	36	18				**65**
	Forestry	1			1			26	17				**45**
	Protected forest		3					7	4				**14**
	Logging			1				3	2				**6**
	Fallow	3					1	8					**12**
Cultivated Land	*Agroforestry*					1		4	1				**6**
	Agriculture			3		12		4	1	1			**21**
Grassland/ Shrubland/ Desert	*Ranching*			1		2		1					**4**
	Non-used grassland/ shrubland/desert							6	2				**8**
Wetland	*Wetland cultivation*												
	Non-used wetland										3		**3**
Total		**4**	**9**	**5**	**3**	**16**	**3**	**95**	**45**	**1**	**3**		**N = 184**

Table 1 also reveals other important land-use change scenarios, for example the change of land use for agriculture/ranching towards fallow holding, which is covered by 14 cases in the scenario sample. In contrast, we identify only 8 cases of converted fallow holdings for agricultural purposes and 1 for ranching. There are also an important number of cases (14) that analyze the transformation of protected forest. Very few studies (5) in our sample delve into the reverse process, i.e., land-use change scenarios towards protected forest (or other protected zones). While these transformations may indeed be less frequent, this relatively low number of studies at the micro-level—at least when our inclusion criteria are applied—is surprising. Furthermore, the small number of cases focusing on the conversion of wetlands for agricultural purposes reveals the lack of research on, amongst others, the transformation of mangrove forests, which have been declining at a faster rate than adjacent inland tropical forests [21]. Additionally, only three cases consider land-use transitions from non-used forests/forestry to logging. The low number of studies examining logged forests maybe explained by the fact that logging is predominantly carried out on large-scale concessions [22]. Further, we could not find any studies that analyze the contribution of agents—who conform to our definition of micro actors—to systematic logging. This could be because logging activities carried out by households, might be illegal and thus less likely to be reported in household surveys [23].

3.2. Geographical Coverage

The studies in our sample were carried out in 29 (sub)tropical countries (see Figure 2). South America accounts for the largest share of studies in our sample (41 percent) and together with Central America, it contributes to 63 percent of all the studies reviewed (see Table 2). This result is in line with the earlier review by Geist and Lambin [10] who find that the majority of case studies come from Latin America.

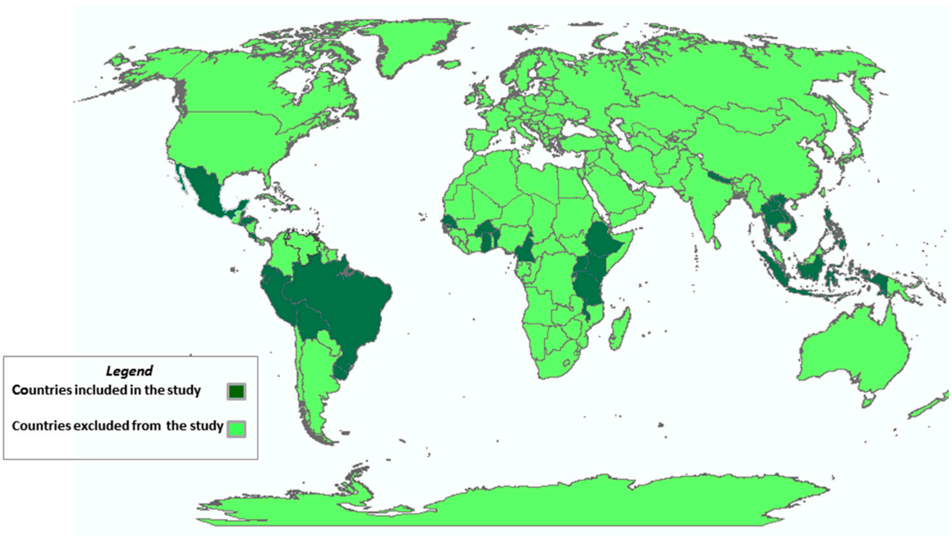

Figure 2. Geographical coverage of micro-level case studies on land-use change across (sub)tropical regions in the period 2000–2015.

Table 2. Regional coverage of reviewed micro-level case studies on land-use change across (sub)tropical regions in the period 2000–2015.

Region	*Central America*	*South America*	*Africa*	*Asia*	*Total*
No. of case studies	20	37	20	14	91
Percent	22	41	22	15	100

This large share can be attributed to the high deforestation rates in Central and South America, which hold the major share of earth's primary forest cover and stocks in forest biomass [24,25]. The high number of studies in this region could also be a result of regional preferences by research groups and the related availability of land-use data. Land-use change studies on African countries account for 20 percent of all reviewed case studies; however, the bulk of these studies (N = 13) are conducted after the year 2010—pointing at the rising importance of land-use change in African countries [26]. Only 15 percent of all case studies analyze land-use change in Asian countries. The limited number of Asian case studies is surprising, since research hints at high deforestation rates in South-East Asia due to logging activities and plantation agriculture [22,27,28].

As noted above with regard to the lack of studies on logging, firms that operate such logging or large-scale agricultural activities appear to remain beyond the scope of micro-level studies of land-use change determinants.

3.3. (Inter)disciplinarity

Ideally, land-change science integrates natural, social and geographical sciences to understand patterns of land-use change [4]. We examine which disciplines are most actively involved in land-use change research and to which extent these disciplines collaborate. This is done by scrutinizing the authors' educational qualifications and their current research interests. Table 3 provides a summary of the disciplines that are involved in land-use change research according to the studies reviewed. Within all case studies, most research is done by economists and geographers, followed by ecologists. Moreover, about half of the studies are multidisciplinary (N = 47) and this share remains relatively constant over the period from 2001 to 2015.

Table 3. Scientific disciplines in micro-Level and land-use change case studies reviewed.

Discipline	Sub-Discipline	Contribution to Reviewed Land-Use Studies (Percent)
Economics	Agricultural Economics, Forest Economics, Environmental Economics, and Resource Economics	41
Geography	Spatial Analysis and Spatial Planners	29
Ecology	Environmental Sciences, Ecology, Biology, Botanic, Forestry, Biogeochemistry, Agricultural Science, Oceanography, Biostatistics, Entomology, and Soil Science	15
Anthropology	Anthropology	10
Social Science	Sociology, Political Science, Development studies, Public policy	2
Demographic Science	Demography, Population Science	3
Multidisciplinary studies (at least one differing discipline)	-	52

3.4. Methods and Data

We aggregate all methods used into five categories that comprise regression analysis (including choice models), multivariate analysis, descriptive statistical analysis, theoretical models, and (data-based) simulation techniques. Some studies use multiple methods, which results in 106 methods applied in 91 studies. Table 4 shows that regression analyses account for 70 percent of the methods used. In addition, a few studies (9 percent) rely on multivariate analysis (for example ANOVA, Hazard models) or on simple descriptive techniques, such as correlation analysis. 10 percent of all applied methods are simulation techniques and out of these, half of the studies use agent-based modelling systems. We do not find that the disciplinary background of the authors determines the choice of methods used.

Table 4. Methodological approach in micro-level land-use change studies.

Method	Percent	N
Regression analysis	59	62
Multivariate analysis	9	10
Theoretical model	6	6
Descriptive analysis	16	17
Simulation techniques	10	11
	100	106

Most studies analyze land-use change using household and/or village data, relying often on relatively small samples of 100–200 observations (see Figure 3).

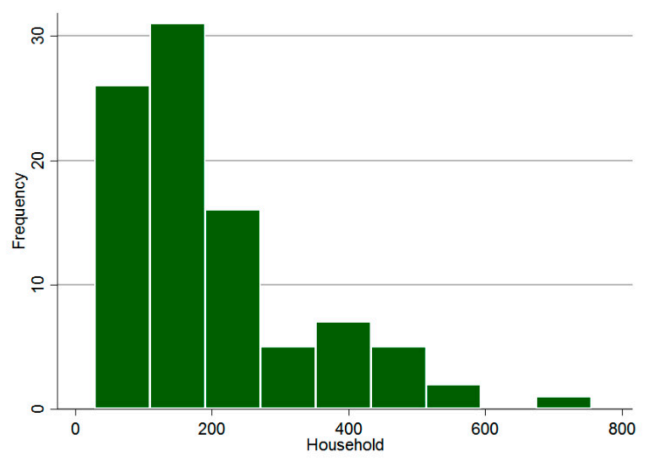

Figure 3. Sample size of household data in reviewed case studies. Note: For the graph one study with a sample size of 3554 households has been excluded.

Moreover, 48 percent of all studies integrate socio-economic data and information from satellite images (N = 45). Only a few studies (explicitly) include qualitative data, such as results from focus group discussion or expert interviews (N = 4). Though most studies explore between-household variation, i.e., household-level data, 8 percent (N = 7) of all studies are based on village-level data. Some studies use also more than one database, which leads to a total number of databases of 93.

In terms of temporal dimension, most studies are based on cross-sectional data, and only 16 studies use panel data with typically two rounds of observation (see Table 5). Beyond that, some studies rely on retrospective data (N = 6) although this approach is prone to measurement errors, for example through recall biases, which especially increase for longer periods [29].

Table 5. Methodological approach in micro-level land-use change studies.

Spatial Level	Cross-Section Analysis	Panel Analysis (t = 2)	Panel Analysis (t > 2)
Household or farm level	51	15	8
Village level	5	0	2
Regional Level	5	1	2
N	61	16	12

3.5. Internal and External Validity

Before providing some meta-analytical insights on the results of the studies, we briefly discuss some of the methodological challenges one is likely to encounter in the analysis of the micro-level drivers of land-use change and then explain how the studies reviewed have dealt with them. One of the key empirical challenges is revealing a truly causal relationship between a specific driver and the dependent variable. While some studies do their best to address the challenges of causal inference, other studies face problems of internal validity because of endogeneity (simultaneity and reverse causality) and omitted variable bias. If these possible sources of bias are not accounted for, a correlation between land-use change and changes in a specific driver (or rather a proxy of it) is mistaken as a causal effect of the latter on the former.

In a number of studies, these empirical (econometric) problems are not adequately addressed. When estimating the causal effects of household-level variables (agents' endowments, off-farm employment) on land use, the results may often be biased because of reverse causality and simultaneity, i.e., not only is the driver influencing land-use change, but also vice versa. For instance, if household wealth (or income) and a particular land use, such as cash cropping or ranching, are found to be correlated, this does not necessarily imply that wealthy households are more likely to be engaged in these land uses. Such a correlation is also likely to reflect that engaging in these commercial activities may have made households wealthy in the first place. A similar argument can be made for off-farm employment—a variable that is often used as an explanatory variable in land-use change regressions. Here, reverse causality stems from the fact that the proceeds from cash crop farming enable otherwise liquidity-constrained households to invest in off-farm activities. More generally, both theory and evidence suggest that rural households that are constrained on important factor markets—most notably labor and credit markets—decide simultaneously on agricultural and non-agricultural production as well as consumption. This simultaneity is formalized in agricultural household models.[4]

At the household level, another potential source of bias—often ignored in empirical land-use change studies—is the so-called "unobserved heterogeneity". In particular, regression analyses of technology adoption or market participation, i.e., cash crop adoption and land-use change, suffer from omitted-variable bias. Households may have unobserved characteristics, such as their intrinsic motivation or entrepreneurship skills, engagement in rent-seeking behavior, or risk-attitudes that directly explain their patterns of land-use change. Such unobserved characteristics tend to be correlated with some of the typical household or farmer characteristics included in regression analyses, for example education, income, and wealth. If unobserved characteristics are omitted from the estimation equation, the effects of these variables are likely to be biased.

Omitted variable bias is not only a problem at the household-level. A particular challenge of empirical studies at the micro level regards disentangling the effects of policies that tend to affect all studied households and individual (household-level) effects. Large-scale land-use change is often the result of deliberate planning policies, in particular agricultural and settlement policies. These policies establish infrastructure and create markets. Households react to these policies and incentives by moving to the agricultural frontier, and engaging in cash crop farming (sometimes through contract farming). This implies that empirical studies in such contexts need to account for the fact that there is a policy that simultaneously causes roads to be built, migrants to move into a certain area and to engage in a specific land use. It is obvious, that the correlation between roads and deforestation that will be observed in such a context cannot be interpreted as a causal effect.

Finally, another very severe problem of reverse causality often arises, when the effect of institutions on land-use change is analyzed. Property rights at the agricultural frontier are often obtained directly by deforestation. This implies that a correlation between insecure property rights (acquired by deforestation) and land-use change cannot be taken as a sign of a causal relationship from weak institutions to deforestation. All these challenges pose serious threats to the internal validity of micro-level land-use change studies, i.e., to correctly attributing causality to specific drivers of land-use change. These challenges are addressed in only 17 of the 57 regression analyses by using

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4 See Taylor and Adelman [30] for an accessible overview.

Instrumental Variable (IV) techniques or fixed effects estimations. This includes the studies by Shively and Pagiola [31], Maertens et al. [32] and Chibwana [33]. The application of these techniques is taken as a proxy that the study has made an explicit effort to reflect upon issues of endogeneity. We acknowledge that this is not to say that these issues have been addressed convincingly by the respective study. In principle, these empirical problems do not apply to simulation and theoretical models (with the exception of regression-based simulations). Here, assumptions, functional forms, rules, and parameters have to be put under scrutiny. Very few studies, however, rely on very stylized optimization models (N = 2).

Studies dealing with land-use change on the micro-level may also face difficulties of external validity. Since micro-level studies have per definition a small geographical coverage, they have to be clear in their contextualization also referring to the representativeness of their results. However, some studies fail to differentiate between the mechanisms specific to the study area and possibly generalizable results. For example, the insights on the impact of a particular set of communal rights on land may only be relevant in the respective context. This holds in particular for drivers related to institutional and policy change.

3.6. Overview of Covered Drivers

In this section, we present some first generalisations on the drivers of households' land-use decisions analysed by the reviewed case studies over space and time. This indicative analysis is based on the frequency of a reported driver that is found to have a significant effect on land-use change. Since many studies are not using regression models, our interpretation of significance does not only refer to statistical significance, but also classifies as significant those drivers that are stressed most by authors within the result or conclusion section. We classify the 330 variables that were reported as significant land-use change determinants in the case studies into seven main categories of drivers (institutions, infrastructure, endowments and characteristics, markets, technology, key policies, and demography refering to population and migration) (see Appendix A, Table A2).[5]

Our findings reveal that household endowments and characteristics account for 42 percent of all identified drivers (see Figure 4). This is followed by markets and infrastructure, representing 14 percent and 13 percent of the drivers reported in the studies; demography, technology, key polices, and institutions play a minor role in driving land-use change in the studies reviewed. Since household endowments and characteristics emerge as the most prominent driver, we further disaggregate this driver into physical-, human- and social capital and labor (see Appendix A, Table A3). Among the household endowments, physical capital is often found to be significantly associated with land-use change. In addition, labor and human capital also receives considerable attention (see Table 6).

These meta-analytical findings need to be interpreted with caution. They cannot be directly taken as evidence that household characteristics and endowments are the most important driver of land-use change.

For their interpretation, it is important to understand that the findings reflect the level of variation between households. In micro-level studies, households tend to be exposed to the same socio-economic and ecological environment; be it with regard to prices, other market conditions or institutions. Detecting land-use change in response to changes in the households' environment typically requires variation and data over time; and as seen above, less than half of the studies have such data. That scale matters for the results, becomes apparent when we disaggregate the studies into different scales distinguishing between data collected on the household, village or regional level. Then it turns out that demography is the most important driver of land-use change on the village level. This finding points

[5] The seven categories of the land-use change drivers are derived from the conceptual framework, consisting of the five micro-level drivers and, additionally, key polices and demography (population/migration) as underlying causes, that are directly linked to the households' decision-making processes on land.

at the importance of migration for land-use change since demographic variation between villages is mainly driven by migration, not by natural demographic forces.

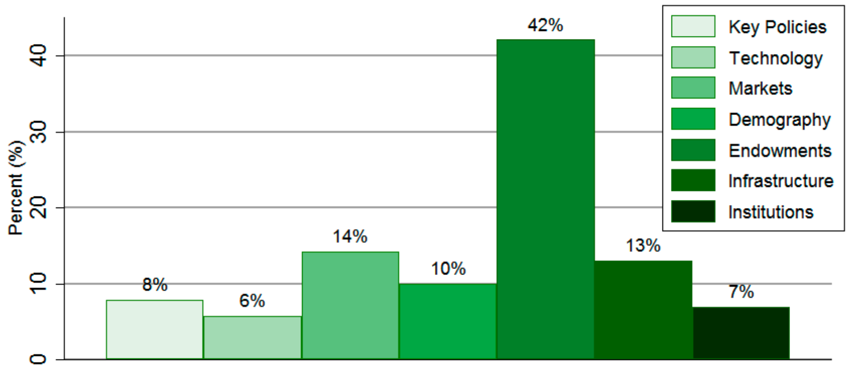

Figure 4. Micro-level drivers of land-use change (N = 330).

Table 6. Decomposition of the micro-level driver: Household endowments and characteristics.

Household Endowment and Characteristics	*Physical Capital*	*Labor*	*Human Capital*	*Social Capital*
%	50	33	14	3

Once the caveats to the above aggregation exercise of drivers are understood, the meta-analytical findings first tell us that there is indeed substantial household heterogeneity, not only in terms of household-level characteristics, but also of observed land-use choices. Second, the household heterogeneity, in particular in terms of income and endowments, is significantly associated with land-use change. It is important to note that this is not necessarily the case, as one may expect household-level land-use change to be driven mainly by external forces with all households reacting more or less the same. In contrast, the detailed review of selected studies below will illustrate how household-level factors condition households' reaction to these external forces. Third, in addition to this general insight regarding the heterogeneity in household characteristics and reactions, the results of Tables 5 and 6 can be taken as a first indication that economic growth is an important aggregate force that drives land-use change. This is because the micro-level determinants of economic growth, in particular physical capital, often turn out to be associated with households' land-use decisions.

However, the relationship between land-use change and these growth- associated micro-level drivers is not simple. As the subsequent literature review will show, there are complex interactions between these micro-level determinants, for example in the use of capital and labour, the application of technologies, and context-conditions, in particular institutions, policies and the conditions on factor markets.

4. Drivers, Studies and Cases of Households' Land Use Decisions

We organized the review below according to the grouping of seven drivers suggested above. In addition to the factors that have been considered in earlier reviews, we carefully review household endowments/characteristics as well as key policies addressing land-use change. The many examples and case studies illustrate the complex interrelationships between land-use change and its supposed drivers. Different transmission channels with varying importance in different contexts are at work, often simultaneously. Empirical ambiguities do not only arise from different context conditions, but also because of the existence of non-linearity's in the relationship between a specific driver and land-use change.

4.1. Property Rights and Institutions

In a setting where households draw their sustenance from agricultural activities, the rules and institutions that govern the ownership and utilization of land play a key role in determining households' behavior and decisions. A significant number of the households analyzed in the studies reviewed are faced with weakly defined and insecure property rights [34–42].

In the absence of well-defined property rights and tenure security households often gain de facto land rights through deforestation and land clearing [34,38,42–44]. Cattaneo's [44] simulation model-based analysis of deforestation in the Brazilian Amazon assumes that deforestation enables the acquisition of property rights to "unclaimed" land. He further argues that this adds a speculative value of informal tenure rights to the potential returns from agriculture. These relationships imply an ambiguous effect of tenure security on deforestation or other forms of land-use change. In general, households or farmers in environments with relatively insecure rights may tend to use land conversion or possession of "unclaimed" land as a way of establishing informal land-use rights. In line with this argument, Dolisca et al. [38] find that illegal occupants are more likely to convert forest into cultivable land than farmers with titled land in Haiti. Such behavior is reinforced by regulations that foresee titling through adverse possession; that is, farmers acquire titles after physically living on a piece of land for a 20-year period. Yet, Dolisca et al. [38] also point at evidence for the same country that shows that titling programs have equally caused more deforestation, as more land is then cleared because of an increased value of the property rights established by clearing—this is very much in line with Cattaneo's [44] argument above. Generally, households will deforest or clear land up to the point where the marginal benefits of clearing (including both the value of potential agricultural production and of tenure rights) exceed or match the marginal costs of doing so (including the direct costs of clearing, for example labor costs, and of violating laws).

Beyond these "direct" effects of establishing property rights through land conversion, the presence of insecure tenure has important effects on agricultural management practices, profits to be earned from agricultural activities, and, hence, investment decisions. It is well established that insecure property rights have an inverse relation with household's planning horizons [45,46]. With shorter planning horizons, farmers are more likely to apply less sustainable agricultural management practices; in particular, they may invest less in soil conservation measures and leave too little land fallow. In line with this argument, Damnyag et al. [43], show that farm households in Ghana are more likely to invest in shade grown cocoa and other perennial crops when they have a secure land title.[6] One should note that these decisions might still be optimal for the individual household under the constraints faced. Less sustainable agricultural practices may eventually lead to land degradation and to possibly higher rates of conversion of non-cultivated to cultivate land again.

In household surveys, the common practice in collecting information on land tenure and property rights is to include questions that either specify the characteristics of land tenure arrangement (customary or freehold, titled, rented or leasehold, share cropped) or that ask about the land acquisition process (inheritance, leasehold, purchase or illegal use) [38,43]. In cases where land titles are absent (or no information is available), property rights may be proxied through the duration of residence [38]. These measures and proxies are typically used as explanatory variables in equations that explain land-use change. This procedure is not without problems, as it neglects the possibility that causality may be reverse: for instance, it assumes that land-use decisions are determined by property rights and not vice versa. However, the act of forest clearing may be observed because this decision gives rise to some kind of property right.

The feedback between land rights and land-use change is illustrated in a study by Otsuka et al. [42] who use data from Sumatra, Indonesia. They show that customary land rights

[6] Such behavior is confirmed by Ali et al. [47], who evaluate a pilot land regularization program in Rwanda. Their results suggest that the program was significantly associated with the higher investment in soil conservation.

respond to changing context conditions, in particular higher population pressure, by giving higher tenure security to households that invest more, specifically through planting trees, into land acquired by clearing communal forests.

4.2. Market Accessibility and Infrastructure

Households' land-use choices highly depend on access to infrastructure and markets. Infrastructure networks and market integration determine households' production decisions. This is because they influence economic structures beyond agriculture, i.e., income-generation opportunities in non-agricultural sectors with possible repercussions on land-use change. Hence, on a gradient of market integration, the production costs of agricultural commodities, the marketing networks, and the opportunity costs of engaging in agriculture differ and so will households' land uses. The interrelation between developing markets and infrastructure extension is twofold: First, infrastructure can be triggered by developing markets, cash crop adoption and economic growth—possibly reinforced by spontaneous in-migration. Secondly, infrastructure extension can be a component of rural development and settlement policies and exogenously drive market integration. In reality, this process will often be iterative and both channels will reinforce each other.

Similar to earlier reviews [9,10], recent empirical findings confirm a strong impact of changing market integration on households' land-use decisions [48–50]. Better access to markets is found to be positively correlated with the extension of agricultural areas, especially for cash crop cultivation [35,51–53]. Accordingly, a number of studies find a negative relation between distance to market centers and deforestation [54–59].

Most studies capture the effect of accessibility to markets on land-use change by controlling for infrastructure variables, such as *distance to markets* [60] or *distance to all-year roads* [32]. As outlined above, interpreting the correlations between these variables and land-use change decisions as causal may be problematic. This is because neither the establishment of infrastructure nor the development of markets (the latter even much less) can always be considered to be exogenous to the household's decision. Instead, both land-use change decisions as well as the establishment of rural infrastructure may be driven by the same—unobserved or omitted—factors, for example a rural development policy aimed at cash crop expansion. Furthermore, capturing market accessibility via distance variables is prone to ignore underlying variables, for example failing output and input markets.

Some studies provide very instructive insights on the relationship between infrastructure/markets and land-use change. Cattaneo [44], for example, uses a dynamic computable general equilibrium model to analyze the impact of infrastructure extension on deforestation in the Amazon. He explicitly considers the response of commodity markets and finds that a 20 percent reduction in transportation costs for all agricultural products leads to an increase in deforested land between 21–39 percent.

Other studies, however, suggest a more complex relationship between market access and land-use change. Using cross-sectional village-level data combined with GIS-data from Central Sulawesi, Indonesia, Maertens et al. [32] analyze how improved technologies in the lowlands affect agricultural expansion and deforestation in the uplands. In doing this, the authors also control for market access of households. Their findings suggest an inverse U-shaped relation between market access and agricultural expansion and argue that improved market access and declining transaction costs lead households to expand their land for agricultural production. However, at a later stage, households start to invest in off-farm activities, which in turn reduce the pressure on the forest. Müller and Zeller [60] combine satellite imagery and survey data from Vietnam to analyze the land-use dynamics in the central highlands of Vietnam econometrically. They find that a period of land-intensive agricultural expansion (at the expense of forest) was followed by a second period of labor and capital intensive agricultural growth. This pattern of agricultural growth without further land expansion was mainly driven by increased market integration that eased constraints on agricultural input and output markets.

4.3. Household Characteristics, Income and Wealth

Household characteristics and endowments are crucial determinants of households' behavior and are often included as control variables in regressions even when they are not the main motivation behind the study. Education levels, income, wealth/assets, gender and age of the household head are commonly controlled for in regression analyses of land-use change. Furthermore, households' endowments with land, physical capital, and (family) labor are important determinants of land-use change decisions, but these will be discussed in the subsequent section.

The conceptual framework above clearly shows the rationale for including education and income as explanatory variables into land-use change regressions. Yet, most studies could be more explicit about the reduced-form character of this type of exercise. In addition, endogeneity issues remain largely unaddressed in most studies. Education, gender and age, for example, affect the productivity and opportunity costs of most economic activities (in off-farm activities often more than in farming). At the same time, they affect values and attitudes of all kinds, for example the valuation of work as a farmer or consumption aspirations. Hence, the effects observed in a regression of land-use change on education (or age) will always reflect a combined (reduced-form) effect of these different transmission channels. Instead of acknowledging this, most studies tend to present an eclectic interpretation of the relationship between a specific household characteristic and land-use change. For example, Codjoe and Bilsborrow [61] and Dolisca et al. [38], point at a possible effect of education through increased consumption aspirations. Busch and Geoghegan [62] stress the importance of education for the profitability of off-farm and/or non-agricultural opportunities at higher levels of education. While the hypothesized effects are likely to be at work in the respective cases, there may be other relevant transmission channels of education to land-use change. In addition, most studies fail to note that formal education is typically correlated with unobserved abilities (of different kinds, for example logical reasoning), which again tends to bias the measured effects.

In particular in the absence of functioning labor markets, the availability of household labor, i.e., the composition of households in terms of age and gender, will affect agricultural production decisions and thus land use change [63]. Perz [63], for example, finds that the number of both old and young household members is correlated with the cultivation of annuals and perennials, no such correlation can be detected for pasture. The relationship between income and land-use change is the most important and interesting, but empirically most challenging one. It is common for empirical micro-level land-use change studies to find a positive correlation between income and bringing land under cultivation [64,65]. We have already pointed at the obvious problem of reverse causality in this relationship above, i.e., income determines the household's current land use and, at the same time, this land use also influences income levels. Yet, very few studies make an attempt to address this problem. One exception is Caviglia-Harris and Harris [66] who use lagged variables of income—instead of current income—in their analysis of cattle ranching expansion in the Brazilian Amazon. They find a positive correlation between income and pasture but not for cropland.

Off-farm income is often explicitly considered in analyses of land-use change as an important component of income of many rural households. It can reduce households' dependency on agriculture and, as an important alternative income generation strategy, determines the opportunity costs of engaging in agriculture [48,67]. At the same time, off-farm activities may provide the liquidity required to invest in certain agricultural activities that need some initial investment, for example livestock or certain cash crops. Most studies do not make an attempt to disentangle these effects, but they confirm a net reduction in deforestation due to increased off-farm income. As the income portfolio and hence income, are simultaneously determined (by the same factors), the empirical caveats in terms of a causal relationship between off-farm income and land-use change mentioned above, also apply to on-farm income.

Setting these concerns aside, the Mexican case study from the southern Yucatán, by Geoghegan et al. [68], finds that households' income generated through off-farm employment is found to be negatively correlated with forest clearance. In one of the few panel data studies, Rodríguez-Meza et al. [69] empirically analyze the determinants of households' land use in El Salvador. Controlling for household fixed effects, they also find that households' engagement in income diversification through non-farm activities reduces land clearance. Pender et al. [70] examine the determinants of land management in Uganda using village-level data. The results suggest six different development pathways where one is related to increasing non-farm activities. The study points at another interesting effect of higher opportunity costs for labor. The pathway of increased off-farm opportunities seems to enhance soil degradation since less household labor is available for more sustainable practices. Similarly, the pressure on (local) labor markets by better-paying off-farm opportunities may encourage switching to less labor-intensive crops. For example, Newby et al. [36], mainly attribute the increase of smallholder teak plantations in Northern Laos to such an effect.

Access to and the availability of capital may also considerably raise households' income levels. Access to capital may not only be required to finance investment costs, for example to set-up a rubber or oil palm plantation, but also to finance fertilizer and other inputs. These are two important related, but yet separate transmission channels that would probably result in ambiguous dynamic effects of access to capital—facilitating agricultural expansions initially and saving land later. To date, however, the literature has little to say on these possible dynamic ambiguities, which are also difficult to assess empirically. This is, for example, because capital incorporated in established farming activity is often not easy to measure. This may explain why the reviewed studies typically hypothesize a positive correlation of the availability of physical capital with agricultural land use. This conceptual weakness is reinforced by the fact that the problems of endogeneity and attribution of causality, which are similar to those with regard to income, are often not addressed. While some studies directly use capital endowments to explain land-use change, others recur to access to capital. It should be noted that the estimates of the effects of the latter variable are also prone to suffer from endogeneity biases, as access to capital is typically determined by the same unobserved factors that determine land-use change, for example entrepreneurial or farming ability. Despite these shortcomings, the fact that capital (or access to it) is often found to be correlated with land-use change has some empirical content and points at the important role of capital. A number of studies suggest that capital is an important driver of deforestation for ranching and agriculture purposes [8,52,53,56,62,63,65,71]. The "effect" of capital on land-use change can be very large. For example, using data on 132 households from Uruara county in eastern Brazil, Caldas et al. [72] find that households with some capital (measured as durable goods available to the household upon arrival on the property) deforest between 20–30 hectares more of forest than poorer households without any capital (the mean farm size in the study is 23 hectares). In addition, access to capital is also found to be associated with the adoption of longer term and higher yielding activities such as the cultivation of perennial cash crops and adoption of pasture in a number of studies [63,73,74]. Kaminski and Thomas [48] investigate the impact of institutional reforms within the cotton sector on households' land uses in Burkina Faso, Africa. The authors combine a structural framework with cross-sectional regression analyses to show that the increase in cotton cultivation can be linked to both the enhanced access to credits and improved credit conditions after institutional reforms.

While education, income, capital accessibility and wealth are certainly among the fundamental drivers of land-use change towards agricultural use, they are often reinforced (or mitigated) by social networks and other forms of social capital that are likely to play an important role particularly in the diffusion of certain crops or agricultural technologies. They facilitate learning by observation and provide farmers with local knowledge of soil quality, suitable agricultural technologies and crop marketing when extension services and other forms of formal institutions are absent. Busch and Vance [75], for example, develop a theoretical model that focuses on the role of information spill-overs in spurring the diffusion of pasture in the southern Yucatan for groups of households originating from the same villages. They find that increases in village networks raise cattle adoption at a decreasing rate. Similarly, Vanwambeke et al. [74] find that belonging to a social network is positively correlated with a household's increased use of inputs (intensification) in irrigated areas in Northern Thailand.

They also use village membership as a proxy for membership in a social network. Their analysis is limited to short-term effects and they do not find evidence for the decreasing positive impact of social capital reported in Busch and Vance [75].

4.4. Input and Output Markets

In developing countries, rural smallholders typically face considerable constraints on input and output markets. While constraints on output markets generally hamper agricultural expansion, imperfections on capital, labor and other input markets may have ambiguous effects. On the one hand, they may also simply constrain expansion; on the other hand, input factor and input market imperfections may lead to substitution of these factors for land and thus promote land-intensive agricultural strategies.

This mechanism is shown by Busch and Geoghegan [62] who analyze land-use choices of rural households in the southern Yucatán region in Mexico. Using a cross-sectional survey, the authors show that labor scarcity drives households' expansion in cattle ranching, which is more intensive in land and capital than in labor. However, intensification of one sector can alter returns to factors and thus reduce pressure on land. In his case study on Philippine farm households at rainforest margins, Shively [76] illustrates the effect of agricultural intensification in a context of a dichotomous lowland-upland economy. He estimates a theoretical model of lowland agricultural production with a model of labor allocation on a representative upland farm and finds that upland forest clearing and hillside farming are reduced by agricultural intensification in the lowlands (in this case, the introduction of irrigation). Higher labor productivity in the lowlands increases demand for labor from the uplands and creates a small but significant reduction in the rate of forest clearing.

A typical finding of micro-level studies with regard to labor is the correlation between deforestation and agricultural extension and the use of hired labor (for example, [66,77–79]), particularly for commercial agriculture [78]. Unfortunately, these studies do not take into account that hired labor is endogenous to land-use change: Labor use, be it family or hired labor or a combination, is always determined by the production technology and labor market conditions, i.e., wages and the availability of labor for hire—rather than vice versa.

In the same study, Kaminski and Thomas [48] also theoretically analyze the role of price fluctuations and the role of marketing risk for household's crop choices; hence looking at product markets. To account for the importance of price fluctuations, Kaminski and Thomas [48] include the relative variability of crop prices as a proxy. They find that optimal land use is also determined by the relative risk-profitability of households' crop portfolios, which are a function of households' technologies and input and output prices. This study illustrates the important role of output markets as a central driver of households' production decision and land-use change, as does another study by Caviglia-Harris and Harris [54] on the impact of settlement design in the Brazilian Amazon. Based on panel data of Brazilian households, who are predominantly small-scale farmers, the authors find a short- and a long-term impact of fluctuating milk prices on deforestation: First, increasing milk prices translate directly in higher income and encourage agents to intensify agricultural production. Then, labor is drawn away from forest clearing. In the longer term, increasing milk prices however raise incentives to extend the production, which leads to further forest clearance to support larger cattle herds.

The effect of new markets has received surprisingly little attention in the literature. One exception is Hought et al. [80] who examine land-use change in Banteay Meanchay Province, Cambodia. The study that combines remote sensing data with field interviews suggests that a sharp increase in (regional) demand for biofuel feedstock has been associated with a rapid expansion of cassava production at the expense of forests. While energy demand drives land-use change in this case, an important secondary effect of cattle ranching is pointed at by Luisana et al. [81]. Using a spatially explicit ecological-economic model, they consider the twofold land-use change of cattle ranching, on the one hand, and the associated cultivation of feed resources and fodder, on the other.

Finally, recent analyses of land markets stress the role of speculation. For example, Takasaki [82] uses a theoretical model to show that, if labor and land markets exist, increasing land prices may promote forest clearing for speculative land holding. The case study of Carrero and Fearnside [83] provides the corresponding empirical evidence for the role of speculation in land holding in their analysis of land-use strategies of households in one of Brazil's deforestation hotspots along the Transamazon Highway. Their case study results suggest that at least 30 percent of surveyed farmers acquire land for speculative reasons.

4.5. Adoption of Agricultural Technology

The availability of and the capacity (and willingness) to adopt agricultural technologies is a key driver of land-use change. Once a technology is chosen, it will determine smallholders' factor use and the respective output level. Hence, the technology applied by households determines land uses and may induce land-use change depending on the specific characteristics of the technology. These technological characteristics that include the level of substitutability between input factors, interact with household endowments, such as the availability of family labor, and prevailing factor market conditions, for example the availability and price for hired labor. Once new agricultural technologies are adopted, they may lead to technological spill-over effects within villages and communities.

Recent studies on the impact of technology on agriculture examine technology as a land-saving or land-consuming driver of land-use change. Empirically, these studies focus on the use chemical inputs [69,84], irrigation systems [31], or mechanical tools [61]. The results are ambiguous: Some studies observe a negative link between the adoption of a new technology and deforestation or agricultural expansion [70,74,85]. However, other studies find evidence for land extensification that is driven by technological improvements [69,86]. In this context, the effects of farm input subsidy programs to encourage the use of fertilizer may also be instructive. Chibwana et al. [33] analyze the effect of the nationwide Farm Input Subsidy Program (FISP) in Malawi. The authors draw on a household survey of 380 households and apply a two-step regression strategy to control for endogenous selection into the program. They find an increased use of inputs for households participating in the FISP and an increase in the area of land planted with maize and tobacco. Furthermore, results suggest that subsidies reduce crop diversity and promote specialization in maize production.

Although these studies show a correlation between land conversion and technology adoption, some of them fail to take the respective market conditions into account, particularly on input markets, as an underlying driving force. Especially in rural regions, area extension due to technical improvements may be induced through relaxed access to formerly constrained input markets. We have already referred to Kaminski and Thomas' [48] study on institutional reforms as the main driver of cotton expansion in Burkina Faso above. These reforms improved access to input markets and to technical advice. Underlying driving factors would need to be factored in not only conceptually, but also in the empirical analysis. The correlation between the use of a technology, for example chemical inputs or mechanical tools, and land conversion may often be traced back to underlying driving forces, such as access to capital or degraded soils.

Moreover, the ambiguity of the findings on the impacts of technological change can be due to differences in elasticities of demand for agricultural products. As has been argued by Villoria et al. [87] and Hertel [88], a productivity improvement can be land-consuming when this demand elasticity is high, as it would be, when innovation happens at regional scale and the product substitutable. However, on the global level, demand for agricultural products is likely to be rather inelastic—close to the demand elasticity for food—and the response to technological change then land-saving [88]. Only a few studies discuss the net effects of new technologies on land use once the technology's impacts on factor use (substitution), factor prices and possibly resulting spill-over effects between regions and sectors are taken into account. In South-East Asia, rural areas are often characterized by an upland-lowland dichotomy. Shively's [76] study of such a context in the Philippines suggests that the adoption of a more labor-intensive technology (irrigation) in the lowlands promotes employment and reduces pressure on forests in both regions: With higher productivity, the factor returns in the lowland increase and lowland wages rise. As a consequence, upland households, who are now employed in the lowlands, pursue an intensification strategy on their own land, which in turn leads to a decrease in forest clearing and hillside farming. Within the same country context, Shively and Pagiola [31] confirm these results using panel data with a focus on the impact of intensification on deforestation. With irrigation development in the lowlands, wages and employment rise and the authors show a positive correlation between the shadow value of lowland labor and the days of hired labor in the uplands. This indicates that upland households employed in the lowlands replace family labor with hired labor on their own farms. The wage-induced increase in labor productivity in the uplands reduces forest clearing and leads to intensification.

Müller and Zeller [60] use cross-sectional regression analysis to investigate the possible land-saving effects of intensification in the Central Highlands of Vietnam. They show that intensification indeed triggers land-saving effects; however, this result is only observed if technological change is accompanied by enhanced market integration and simultaneously enforced forest protection policies. These results are in contrast to those obtained by Maertens et al. [32] who use cross-sectional village-level data combined with GIS-data to analyze the land-use implications of the introduction of hand-tractors in the rice sector in Central Sulawesi, Indonesia. They show that the improved technology for rice cultivation induces a shift of labor into the forested uplands and thus increases agricultural extension and deforestation. The contradicting effects found in these two studies illustrate the importance of context specific conditions, here in particular the labor market conditions, in shaping the effects of technological change.

With regard to the processes of technology adoption, a couple of recent studies have investigated the role of household interaction with the diffusion of technologies. Mena et al. [89] use an agent-based model fed with empirical data, in this study, the authors assume that households transfer information and knowledge through imitation of neighbors' cultivation strategies. Vanwambeke et al. [74] analyze the emergence of cash crop markets and the industrialization of rural households in northern Thailand. Based on cross-sectional household data and remote sensing data, the authors apply a choice model to examine the impact of social-networks on new land-use strategies. The authors show that social networks defined by the number of other adopters in the village lead to intensified land use through information via sharing or observing.

4.6. Population and Migration

There is a consensus in the literature that population pressure is an important driver of land-use change [51,77,90,91] and that it also triggers technological change in agriculture technologies [32]. Since population pressure can only be partially reflected at the household level, micro-level studies on land-use change often incorporate census data into their analysis (see for instance, [32,39,44,51,58,91,92]. More precisely, population growth—often accelerated by migration—can either result in extensive (if uncultivated lands are available) or intensive land use (if uncultivated lands are not available). As many of the areas within the studies reviewed were previously forestland before they were converted to settlements or agricultural lands, the opening of these lands has been accompanied by migration into the previous forestlands. In fact, migration has received considerable attention in the land-use change literature and migration status has in many micro-level studies been hypothesized to affect households' land-use decisions. First, migrants are expected to follow extensive and unsustainable agricultural practices that lead to the encroachment of the forest frontier because they have shorter planning horizons, which cause them to be more destructive than host populations [59] Second, migrants are assumed to use unsustainable agricultural practices due to their limited knowledge of the local agro-ecological conditions of their new region. Codjoe and Bilsborrow [61] find weak empirical support for these hypotheses for migrant farmers in central Ghana, as they tend to have less fallow years than non-migrants.

In a study on colonist farm incomes in the Ecuadorian Amazon, Murphy [41] finds that new migrants earn less because they have less experience about the regional conditions. While this supports the claims made above that new migrants are not familiar with the agro-ecological conditions of their new residence it does not provide any evidence on their land-use patterns. Other studies that show that duration of residence matters for land-use change include Dolisca et al. [38] who find that the longer households have lived in the Forêt des Pins Reserve in Haiti the less likely they are to clear forests.

Using data from Southern Yucatán in Mexico, Schmook and Radel [93] find that households with US based migrants have more pasture than non-migrant households. This is because the establishment of pasture is initially labor intensive but requires very low levels of labor inputs once established which makes it ideal for households with members that have migrated to the US. In addition, they find that migrant households cultivate more summer maize and chili and are less likely to cultivate traditional milpa when compared to non-migrants.

4.7. Key Policies

To analyze the impacts of policies, inter-temporal data that captures the conditions before and after the policy or data from a counterfactual group that consists of households with the same characteristics that have not been exposed to the policy change is necessary [65]. However, since policies are often experienced uniformly within a region, such data is not usually available for most of the studies reviewed in this paper and the analyses are sometimes made with retrospective data that questions households on their experiences before the policy change.

Market-oriented reforms adopted by many developing countries in the 1980s and 1990s played an important role in altering land use in many of the countries covered by the reviewed studies. One of the most extensively studied policies with respect to its land-use change implications is the Programa de Apoyo Directo al Campo (PROCAMPO), a cash transfer program introduced in 1994 in Mexico to mitigate the possible adverse effects of the North American Free Trade Agreement (NAFTA) on rural populations [52,65]. Kleipeis and Vance [52] were the first to clearly establish a link between the receipt of PROCAMPO cash transfers and the subsequent land-use decisions made by farm households. Using a panel data set with individual farm-level data that spans an 11-year period from the southern Yucatán peninsula in Mexico, the authors show that PROCAMPO payments are responsible for nearly 38 percent of deforestation that occurred in the study region between 1994 and 1997. They relate this finding to the eligibility conditions of PROCAMPO that are at odds with fallow regeneration and cause households to clear more forests in order to maintain the cultivation of crops in rich soils.[7] A later study, by Schmook and Vance [65] uses a seemingly unrelated regression to compare the effects of PROCAMPO and another agricultural support program—Alianza Para el Campo—on the households in the same region. PROCAMPO puts no restrictions on how the transfer should be spent, but attaches conditions on how land should be used. Instead, transfers from Alianza are tied to specific agricultural activities that have to be implemented by households [65]. In line with Kleipeis and Vance [52], they find that PROCRAMPO is significantly correlated with a reduction in forest area and with increases in area under pasture and cultivation. In a similar vein, Alianza is found to significantly influence land use, in particular in favor of pasture.

Using recall plot data from 1970 to 2009 in combination with aerial photographs, Ribeiro Palacios et al. [95] examine the broader impact of economic reforms on land-use change in Mexico. Looking at the region of Southern Huasteca, the authors stress that market-oriented policies such as the promotion of agribusinesses are a key driver of a reinforced land conversion for cash crops, especially for citrus orchards. This typically occurs at the expense of food crop

[7] Other studies that analyze the impacts of PROCAMPO such as Busch and Geoghegan [62] and Vance and Geoghegan [53] find similar results. Yet, Busch and Vance [75] and Chowdhury [94] find opposite effect on area under cultivation and fallow, respectively.

agriculture and secondary forests. The finding that market-oriented reforms increased deforestation and expanded areas devoted to agriculture is not unique to south-eastern Mexico. Another example is the abovementioned case of the reform of the Burkinabé cotton sector analyzed by Kaminski and Thomas [48] that included the privatization of the parastatal firm SOFITEX (National Cotton Fibre Company). Going back to Mexico, Barsimantov and Antezana [96] discuss how the adoption of the 1992 Forestry Law and the 1992 Reform of the Mexican Constitution that were part of a set of free market and reregulation policies increased deforestation and later led to an increase in the production of avocados. The authors show that forest cover was reduced considerably because of these policy changes, particularly in the non-forestry communities that had relatively less forest cover to begin with.

Other policies that have played a key role in driving the land-use decisions made by households in the reviewed studies include policies targeted at infrastructure development [60,70] and settlement policies [54]. Caviglia-Harris and Harris [54] show that even when policy makers take extra precautions in designing alternative new settlement policies to ensure that they meet both environmental and social objectives, in the long term the design does not influence land cover choices and that land clearing is extensive in all agricultural lots. After a ten-year period, they find that very little forest remains in the radial lots that are introduced by the new alternative settlement policy.

Prominent examples of land-related policies include the Payment for Environmental Services (PES) and Reducing Emissions from Deforestation and Degradation (REDD and REDD+).[8] These policies directly address households' decisions to deforest by altering the payoffs to different land uses. Therefore, their effects on land-use change depend on the farmers' livelihood and crop options and the related opportunity costs of altering land uses [98]. This is confirmed by Newton et al.'s [99] evaluation of the impact of Bolsa Floresta, a PES scheme with an undifferentiated reward structure in the Brazilian Amazon. They emphasize the heterogeneity among farmers' livelihood strategies that results in a strongly heterogeneous impact of the program on the decision of deforesting. In addition, the schemes' impact also depends on possible differences in farmers' valuations of ecosystem services [100]. Mello and Hildebrand [101] who analyze the potential effects of carbon trade on land-use decisions and farm income of small-scale farmers in the eastern Brazilian Amazon illustrate the importance of sufficient compensation. The authors stress that carbon prices have to be high enough to cover transition costs to adopt land-saving technologies.

5. Conclusions

For this paper, we have reviewed 91 recent empirical and theoretical studies that analyze land-use change at the farm-household level. The review builds on a conceptual framework of a human-environmental system focusing on micro-level agents and resulting land-use change drivers. This concept extends previous work by Angelsen and Kaimowitz [9]. The framework considers feedback mechanisms between the different stages of the land-use change process, for example between the actions of agents and macroeconomic variables, and between specific causes within a stage, for example between different decision parameters such as the interlink between technology options and accessibility of infrastructure. Considering telecoupling interactions, the concept allows for multidirectional interactions of the whole system towards other socially and geographically remote human- environmental systems. Furthermore, our framework explicitly considers the role of household endowments and characteristics as drivers of land-use change.

We first conduct a meta-analysis of the 91 studies. We find that the most frequently analyzed scenario is the conversion of non-used forests or forestry into land used for agricultural purposes—about a third of all scenarios. The second largest share is accounted for by studies that

[8] PES is a policy that compensates land owners and resource managers for the provision of ecosystem services [97]. Providing income to resource managers for ecosystem services encourages sustainable land-use practices. REDD is based on a similar monetary incentives mechanism, it compensates developing countries with income payments that are equivalent to the amount of carbon emissions reduced if their national deforestation levels decrease [43].

look into the conversion of non-used forests or forested areas into ranching. Most studies analyze land-use change using household and/or village data and, in doing so, often rely on relatively small samples of 100-200 observations. There is a clear regional concentration of studies on Central and South America and some studies on African countries, while only 11 percent analyze land-use change in Asian countries. The limited number of Asian case studies is surprising, since evidence hints at high deforestation rates in South-East Asia due to logging activities and plantation agriculture. In our view, this may be explained by the literature's focus on household farms. Yet, the omission of firms that operate logging and large-scale farming activities implies that a key (micro-level) actor's behavior remains unexplored. We find that a number of studies face problems of internal validity because of endogeneity (simultaneity and reverse causality) and omitted variable bias that are not adequately addressed.

When we aggregate the variables identified as drivers in the micro-level studies into stylized categories, we find that household-level heterogeneity and the resulting differences in land-use decisions can be considered a key driver of land-use change. This is less trivial than it may appear, as it is also conceivable that forces external to households, in particular, policies and market signals, are strong enough to dwarf the effects of household-level differences. Among the household-level characteristics, the literature points at micro-level determinants of economic growth, in particular in physical capital, as a catalyst of human induced land-use change.

However, as our detailed literature review shows, the relationship between land-use change and these growth-associated micro-level drivers is complex, in particular because of the interactions between these drivers, for example the use of capital and labor and the applied technologies, and also context-conditions, in particular institutions, policies and the conditions on factor markets. These complexities and interactions cause the abovementioned important challenges in the empirical study of land-use change.

Land governance systems make a good case for the complexities and interactions discussed above. It is well established that the absence of well- defined property rights and tenure security often leads households to gain de facto land rights through deforestation and land clearing. In addition, insecure tenure shortens farmers' planning horizons, which, in turn, makes them more likely to apply less sustainable agricultural management practices. When the impacts of tenure security on land use and management practices are empirically analyzed reverse causality issues, i.e., the fact that tenure security is influenced by land-use and management, receive too little attention in the literature.

Reverse causality is also an often-unresolved issue in a fundamental relationship in micro- level land-use change studies, the relationship between income and land use: Income determines the household's current land use and, at the same time, this land use also influences income levels. Similarly, empirical problems often remain unaddressed in the analysis of the effects of infrastructure development and increasing market integration that some studies also deem to be an important driver of land-use change. More and better infrastructure can be the result of increasing demand caused by cash crop adoption and economic growth, but it can also exogenously drive market integration. The literature too often assumes a one-directional causal relationship and ignores that infrastructure development may well be driven by the same rural development policy, for example one aimed at cash crop expansion.

Complex causal relationships hence complicate the empirical analyses and so do non-linear relationships as well as interactions between different drivers that are also frequently observed. One example for an important non-linearity is the inverse U-shaped relationship between market access and agricultural expansion that has been shown in a number of studies: Improved market access first leads to agricultural expansion, but, in a second stage, households start to invest in off-farm activities and reduce the pressure on forests. Important interactions are at work between factor (land, labor and capital) markets and household characteristics. Factor markets in developing countries tend to be imperfect, which implies that households' initial factor endowments, for example initial wealth or household labor, may play an important role in explaining land-use and management choices. Factor market imperfection and/or limited household endowments may then simply constrain expansion. However, as the same market imperfections may lead to substitution effects, they may also promote land-intensive agricultural strategies. In the case of capital, these ambiguities are reinforced by the fact that capital does not only finance initial investment costs but also current costs for fertilizer and other inputs. This implies that access to capital may facilitate agricultural expansions initially and saving land later. These mechanisms are similar for technology adoption. New technologies, for example the introduction of a new crop, are often found to lead to agricultural expansion. Yet, they may also lead to land savings, conditional on the substitutability between input factors and possible interaction with household endowments and factor market conditions. In terms of household-level determinants of technology adoption, the literature has often stressed that migrant status tend to be associated with the application of intensive and unsustainable agricultural practices.

In sum, the rich empirical literature that has been reviewed in this study, illustrates the complexity of micro-level land-use change processes, in particular the interrelationships between household-level characteristics, factor market conditions, and land-use change. These are conditioned by institutions and policies. The review suggests that market-oriented reforms adopted by many developing countries in the 1980s and 1990s have had an important role in altering land use. The empirical designs of many reviewed studies do not account for the complexity of the land-use change processes properly. While the studies have explored some key facets of household-level drivers of land-use change, future research would greatly benefit from methodological rigor and some more care should be taken when results are interpreted as causal relationships. Yet, does it matter if an empirical analysis does not pay attention to the fact that income is also determined by land-use change and not only vice versa? Yes, it does since the conclusion to be drawn from either finding differs dramatically. If income growth causes deforestation, there are good reasons to worry since most rural households at forest frontiers are still way below income levels that they would consider desirable – and are probably likely to achieve income growth at some point in the future. If incomes, however, have in the past grown for reasons related to land-use change, for example because of growing a cash crop on converted forest, they might in the future grow for different reasons, for example because growing economies tend to become more diversified and people engage more in non-agricultural activities.

We want to close by reflecting briefly on some further implications of this review for the way forward. To generate evidence from local to global levels, the telecoupling framework is a simple but general and common approach to describe the interactions different between human-environmental-systems in a globalized world. It helps to capture synergies and trade-offs across different scales and systems and facilitate global policies to meet relevant socio-economic and environmental challenges. The telecoupling framework demands research on integrated systems, and more empirical studies building on this concept are desirable. Approaches may include both statistical and model-based analyses that combine data from a variety of sources, of course still including survey-based information. This should also enable researchers to extend the sample sizes and increase the external validity of the findings. External validity could also be improved by paying due attention to case selection and some more reflection on whether results should be regarded as context-specific or generalizable.

These approaches may include both statistical and model-based analyses that combine data from a variety of sources, of course still including survey-based information. This should also enable researchers to extend the sample sizes and increase the external validity of the findings. External validity could also be improved by paying due attention to case selection and some more reflection on whether results should be regarded as context-specific or generalizable.

Recently, the wider literature on land-use change has shifted from exploring the determinants of direct human-induced land-use change towards assessing how households (and other agents) can cope with the consequences of global environmental change; thus land-use change indirectly caused by human activity. There are of course important lessons to be drawn from our review for this emerging literature, as the reviewed land-use change determinants are closely related to a household's or farmer's capacity to cope with climate change. Moreover, recent studies often extend their analysis to examine also the implications of land-use change on livelihoods. The latter trend shows that it is increasingly acknowledged that land-use change and household welfare are simultaneously determined.

Most of the studies focusing on land-specific policies combine satellite images with descriptive statistics of field data, which allow first snapshots on economic-ecological consequences of land-use change on broader scales. However, whether these policies are effective over time in actually influencing land-use change decisions is still under-researched. A dynamic analysis using panel data on the plot or household level would be necessary to assess these policies more rigorously. Also impacts of more recent policies, like PES or REDD+, have to be further explored.

Finally, while our review focused on household-level studies, we were surprised to find virtually no study that would have analyzed—at the micro-level—the decisions by firms that operate logging and large-scale farming activities. This implies that a key (micro-level) actor's behavior remains unexplored and this omission partly explains the lack of studies in Asian contexts, where these players are probably more important.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-445X/5/4/32/s1, **Table S1.** Main characteristics of micro-level land-use change studies.

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Appendix A

A questionnaire was constructed to systematically record information from the 91 studies selected to be included in the review (Table A1). The entries were recorded and cross verified by two of the three authors and a research assistant working with the authors (Table A2). The data is available upon request from the authors. For more information on the data entry, please contact the corresponding author at the following email address: elisabeth.hettig@giga-hamburg.de.

Table A1. Review questionnaire.

Question Number	Question/Issue	Comments
1	Who authored the paper?	*List orders according to publication order*
2	What are the academic backgrounds of the authors?	*Here look at the authors academic qualifications and profiles*
3	In which (peer-reviewed) journal was the paper published?	
4	When was the paper published?	
5	On which region (tropical or subtropical) the study focus?	
6	Which country is the focus of the study?	
7	What type of analysis is conducted in the study?	
8	What type of specific methodology is used by the authors in the study?	
9	What type of spatial analysis is used in the study?	
10	What type of data is collected in the study?	
11	When was the household data used in the study collected?	
12	What variable to the authors use to identify land use change?	
13	Which explanatory variables are found to have a significant impact on the land change variable identified in question 13?	*Here only record the variable that are reported to significantly affect LUC*
14	What are the main socio-economic drivers of land-use change identified by the authors?	*Here only include the main drivers that are cited by the authors within the result and conclusion section*
15	How can the drivers identified in questions 14 be classified to match our coding scheme?	*Here classify the drivers in question 14 into the 7 main categories*

Table A2. Coding of reported land-use change drivers.

Reported Driver in Reviewed Studies	Categorization for the Meta-Analysis
Population density	Demography
Population pressure/growth	Demography
Migration	Demography
Agriculture output prices/Cash cropping	Markets
Agriculture input prices	Markets
Off-farm income/Off-farm labor/Off-farm wages	Markets
Hired labor	Markets
Credit (access)	Markets
Farm size	Endowments
Household size	Endowments
Household composition children	Endowments
Household composition gender	Endowments
Household composition labor	Endowments
Household education	Endowments
Social networks	Endowments
Technological progress	Technology
Land property rights	Institutions
Land tenure security	Institutions
(Key) Policies	Key Policies
Market access	Infrastructure
Infrastructure	Infrastructure

Table A3. Coding of reported endowments.

Reported Endowments and Characteristics in Reviewed Studies	Categorization of Endowments for the Meta-Analysis
Farm size	Physical capital
Wealth and capital endowment	Physical capital
Income	Physical capital
Household size	Labor
Household children	Labor
Household labor	Labor
Household education	Human capital
Social networks	Social capital

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