

**AMBIO**

Electronic Supplementary Material

*This supplementary material has not been peer reviewed*

**Title:** Meta-studies in land use science: Current status and prospects

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## Systematic review protocol

We searched ISI web of Knowledge for all meta-studies that reported:

- Human modifications and appropriations of natural processes as causes of observed land cover change, or
- How the impacts of land-use change directly affect natural and/or human system outcomes, or
- A combination of these two

A target set of 12 known meta-studies was first identified to represent the expected range of synthesis methods and research topics present in LCS (Angelsen and Kaimowitz 1999; Guo and Gifford 2002; Geist and Lambin 2004; Keys and McConnell 2005; Misselhorn 2005; Pagdee et al. 2006; Scanlon et al. 2006; Tonitto et al. 2006; Rudel 2007; Schueler et al. 2009; Seto et al. 2011; van Vliet et al. 2012). Keywords are selected from these meta-studies such that all target meta-studies appear in the search results. This yielded the following search string:

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TS=(((meta AND (study OR analy*)) OR "case studies" OR synthes* OR intergrat* OR (meta- AND (study OR anal*)) OR (geographic* AND database)) AND ((land AND (use OR cover)) OR (land- AND (use OR cover)) OR "food *security" OR ((environmental OR forest OR land OR resource* OR "common pool" OR (agricultur* AND production)) AND (management OR economics OR cultivat*))) AND (((proximate OR direct OR indirect) AND causes) OR "driv*" OR crop* OR urban OR rural OR deforestation OR agricultur* OR forest OR dryland OR desertification OR expansion OR intensification OR conservation))
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Refined by: Web of Science Categories=(ECOLOGY OR ENVIRONMENTAL SCIENCES OR ENVIRONMENTAL STUDIES OR WATER RESOURCES OR PLANT SCIENCES OR BIODIVERSITY CONSERVATION OR AGRICULTURE MULTIDISCIPLINARY OR GEOGRAPHY OR SOIL SCIENCE OR METEOROLOGY ATMOSPHERIC SCIENCES OR PLANNING DEVELOPMENT OR AGRICULTURAL ECONOMICS POLICY OR ECONOMICS OR ENGINEERING CIVIL OR SOCIOLOGY OR MULTIDISCIPLINARY SCIENCES OR BIOLOGY )

We further narrowed the number of studies included by the additional condition that:

- Meta-studies were defined as studies that are secondary studies, i.e. based on other previously published primary research, and that are systematic in their analysis, i.e. excluding literature reviews in which the translation between cases and the meta-study findings was not tractable.
- Studies should report on a comparison of two or more discrete situations either in time (before/after) or in space (i.e. using space time substitution).
- Studies should analyze land use change processes or their impacts at landscape scale. As a consequence studies that assess individual crops or crop management practices are not included, but studies that assess farm systems (such as organic versus conventional) are included.
- Studies must be generalizable beyond the set of sample cases analyzed to describe large scale trends
- Be representative of a globally or regionally relevant process, and
- Not be constrained by political boundaries alone.

The systematic search was originally performed in 2012 (Magliocca et al. 2015), and subsequently updated to include all studies published in or before 2014. In addition, we added three studies that did not appear in our search results but were identified by workshop participants, and we added another three studies that did not appear in our search results but were identified by the reviewers.

## Overview of meta-studies in land use science

**Table S1:** Meta-studies analyzing land use change processes.

Meta-study	Land change process explained	Regional coverage	Studies	Observations	Synthesis method*
<b>Agriculture</b>					
Baumgart-Getz et al. (2012)	Adoption of agricultural best management practices	USA	46	46	COMA
Current et al. (1995)	Adoption of agroforestry by farmers	Latin America	21	21	CSC
Keys and McConnell (2005)	Intensification and expansion of agricultural land	Tropics	91	108	CSC
Meyfroidt et al. (2014)	Commodity crop expansion	Tropics	6	6	VOMA
Rey Benayas et al. (2007)	Abandonment of agricultural land	Global	45	45	COMA
Rindfuss et al. (2007)	Agricultural expansion in forest frontiers	Tropics	7	7	CSC
Schmidt-Vogt et al. (2009)	Changes in fallow length and extent of swidden, conversion of swidden	SE Asia	67	151	VOMA
van Vliet et al. (2012)	Changes in fallow length and extent of swidden, conversion of swidden	Tropics	111	157	MAES
van Vliet et al. (2013)	Changes in cropland area	Sahel	25	50	VOMA
van Vliet et al. (2015)	Intensification and disintensification of agricultural land use	Europe	137	218	COMA
<b>Forests</b>					
Angelsen and Kaimowitz (1999)	Tropical deforestation	Tropics	146	146	CSMDA
Geist and Lambin (2002)	Tropical deforestation	Tropics	95	152	VOMA
Mondal and Nagendra (2011)	Deforestation and forest degradation in tiger landscapes	Asia	27	24	VOMA
Pagdee et al. (2006)	Protection of community forests	Global	31	69	VOMA
Robinson et al. (2014)	Influence of land tenure form and security on deforestation and forest degradation	Tropics	36	118	CSMDA
Rudel (2007)	Agents for tropical deforestation (from state run to enterprise led deforestation)	Tropics	268	268	COMA
Rudel et al. (2009)	Tropical deforestation and regrowth	Tropics	268	268	COMA
Rutte (2011)	Sacred areas as community based conservation of natural areas	Global	18	21	VOMA
<b>Urban</b>					
Seto et al. (2011)	Expansion of urban areas	Global	181	326	CSMDA
<b>Wetland</b>					
van Asselen et al. (2013)	Conversion of wetlands into other land uses	Global	88	105	COMA
<b>Multiple land uses</b>					
Geist and Lambin (2004)	Dryland degradation and desertification	Global	54	132	VOMA
Munteanu et al. (2014)	Increase and decrease of forest and agricultural land area	Eastern Europe	66	102	VOMA

**Table S2:** Meta-studies analyzing the impacts of different land uses or land use change processes on biodiversity.

Meta-study	Land uses or land use change processes included	Specific impact	Regional coverage	Studies	Observations	Synthesis method*
<b>Agriculture</b>						
Attwood et al. (2008)	Intensification of agricultural land use	Arthropod species richness and abundance	Global	259	259	MAES
Batáry et al. (2011)	Difference between simple and complex landscapes under agri-environmental management	Species richness and abundance of plants and animals	Global	93	223	MAES
Bengtsson et al. (2005)	Organic farming and conventional farming	Species richness in various taxa	Global	63	180	VOMA
Bremer and Farley (2010)	Conversion to plantations for wood production, soil and water conservation, and carbon sequestration	Plant species richness	Global	36	126	CSMDA
Chaplin-Kramer et al., 2011)	Different levels of landscape complexity	Pests, natural enemies and/or pest control	Global	46	159	MAES
De Beenhouwer et al. (2013)	Conversion of forests into cacao and coffee agroforestry systems	Decline in biodiversity and other ecosystem services	Tropics	74	202	MAES
Fletcher et al. (2011)	Conversion to biofuel cropping	Vertebrate diversity and vertebrate abundance	USA	15	272	MAES
Garratt et al. (2011)	Organic and conventional agriculture	Arthropod biodiversity	Global	71	71	COMA
Kleijn and Sutherland (2003)	Adoption of agri-environmental schemes	General species abundance	Europe	62	62	CSC
Letourneau et al. (2011)	Difference in monoculture cropping systems and plant diversity	Herbivore reduction and herbivore enemy increase	Global	45	552	MAES
Philpott et al. (2008)	Difference in management of coffee plantations	Species richness of ants, birds and trees	Tropics	27	207	MAES
Queiroz et al. (2014)	Farmland abandonment	General biodiversity	Global	276	276	VOMA
Rahmann (2011)	Organic and conventional farming systems	General biodiversity	Global	396	396	VOMA
Ramírez and Simonetti (2011)	Structure and density of commercial plantations	Mammal diversity (size and dietary group)	Global	45	81	CSMDA
Tuck et al. (2014)	Organic and conventional farming, and land use intensity	Species richness for various groups of species	Global	94	184	MAES
<b>Forests</b>						
Bhagwat and Rutte (2006)	Sites protected for sacred reasons	Biodiversity conservation	Global	98	98	VOMA
Bogdziewicz and Zwolak (2014)	Clear-cutting of temperate and boreal forests	Small mammal abundance	Europe	20	156	MAES
Boucher et al. (2011)	Old-growth forest loss and fragmentation due to logging	Biodiversity loss due to edge effects	North-America	9	9	CSC

Cristescu et al. (2012)	Restoration after mining	Fauna recolonization	Australia	71	849	VOMA
De Frenne et al. (2011)	Ancient forests and post-agriculture forests	Recovery rate of floristic species	Europe	18	812	MAES
Duguid and Ashton (2013)	Forest management and regeneration treatment	Plant species richness	North America	37	96	MAES
Gibson et al. (2011)	Forest disturbance and forest conversion	Biodiversity for a wide range of taxa	Tropics	138	2220	MAES
Gray et al. (2007)	Undisturbed forests and selective logging	body size, local population size, and geographic range size of different feeding guilds of birds	Tropics	57	2354	CSMDA
Hill and Hamer (2004)	Undisturbed forests, selected logging and shifting cultivation	Biodiversity of birds	Tropics	37	37	CSMDA
Holloway and Smith (2011)	Various harvesting practices	Abundance of northern flying squirrels	North America	14	14	MAES
Karthik et al. (2009)	Forest recovery following shifting cultivation	Biomass accumulation and species richness	Global	43	43	CSC
Koh (2007)	Deforestation and habitat loss	Butterfly species richness	SE Asia	20	20	CSC
Marczak et al. (2010)	Riparian buffers and unharvested riparian sites	Species abundance of various taxa	Global	27	519	MAES
Mori and Kitagawa (2014)	Selective logging and retention logging	General species diversity	Global	50	221	MAES
Paillet et al. (2010)	Forest structure and composition in managed and unmanaged forests	General species richness	Europe	49	120	MAES
Putz et al. (2012)	Forest harvesting	Capacity to sustain timber production, retain species, and conserve carbon stocks	Tropics	109	109	CSMDA
Rey Benayas et al. (2009)	Forest restoration	Biodiversity and provisioning of ecosystems services	Global	89	526	MAES
Schlossberg and King (2009)	Forest logging	Bird population's response after logging	North America	11	11	MAES
Schmidt et al. (2011)	Harvesting non-timber forest products	Population responses to harvest	Global	48	134	MAES
Sodhi et al. (2009)	Deforestation and forest degradation	Ecological health: richness, abundance, and demographics	SE Asia	120	1074	MAES
Ticktin (2004)	Harvesting non-timber forest products	Ecological consequences of harvesting non timber forest products	Global	70	70	CSC
Vanderwel et al. (2007)	Forest harvesting	Bird species responses	North America	42	435	MAES
Vellend et al. (2007)	Old forest and young forests	Forest species diversity	North America and Europe	11	1446	CSDA
<b>Urban</b>						
Colding and Folke	Golf courses and other green area habitats	Species richness and preservation of fauna	Global	17	190	CSMDA

(2008)		of conservation concern				
Cook et al. (2011)	Various types of garden management	Wide range of ecological properties and functions	North America	256	256	VOMA
Hahs et al. (2009)	Effect of urban developments	Plant extinction rates	Global	22	22	CSMDA
Luck (2007)	Human population densities	Species richness for various taxa	Global	85	401	MAES
Martinson and Raupp (2013)	Urban areas (compared to rural forested sites)	Species richness and abundance of beetles	Global	18	658	MAES
Stewart et al. (2007)	Absence and presence of wind farms, and the time since their development	Bird collision with turbines, habitat loss and disturbance	Global	15	19	MAES
<b>Multiple land uses</b>						
Barral et al. (2015)	Restauration of agroecosystems: land sharing versus land sparing	Biodiversity, as well as a number of other ecosystem services	Global	54	154	MAES
Felton et al. (2010)	Pastures and timber plantations	species richness and abundance for plants, invertebrates, reptiles/amphibians, mammals, and birds	Global	36	145	MAES
Flynn et al. (2009)	Natural and agricultural land use	Species richness and diversity of plant, bird and mammal communities	Global	20	1670	MAES
Gerstner et al. (2014)	Multiple land use types	Species richness of plants	Global	375	572	MAES
Hadley and Betts (2012)	Habitat loss and habitat fragmentation	Animal mediated pollination	Global	303	303	VOMA
Kennedy et al. (2013)	Landscape composition and configuration, farm management	Abundance and species richness of bee pollinators	Global	39	605	MAES
Laliberté et al. (2010)	Various land use types along an intensity gradient	Functional redundancy and response diversity of plant communities	Global	18	18	MAES
Mantyka-pringle et al. (2012)	Habitat loss in combination with climate change	Species density and diversity of a wide range of taxa	Global	168	1779	MAES
Montero-Castaño and Vilà (2012)	Landscape and habitat alteration	Impact on pollinators and the pollination services	Global	58	143	MAES
Murphy and Romanuk (2014)	Disturbed and undisturbed habitats	Decline in species richness	Global	245	327	COMA
Nichols et al. (2007)	Disturbance gradient from selectively logged forest to annual crops, pastures and clear-cuts	Beetle abundance and species richness	Global	33	33	MAES
Prieto-Benítez and Méndez (2011)	Various land management types, including insecticides, forest fragmentation and logging, and farmland abandonment.	Spider abundance and spider biodiversity	Global	174	197	MAES
Tylianakis et al. (2008)	Habitat loss, fragmentation, and increased land use intensity	Pollination, species richness, species interaction	Global	688	688	VOMA
Winfree et al. (2009)	Habitat loss	Pollination, species richness	Global	54	130	MAES
Winfree et al. (2011)	Habitat loss	Pollination, species richness	Global	265	674	MAES

**Table S3:** Meta-studies analyzing the impacts of different land uses or land use change processes on biogeochemical processes. See main text for explanations of the synthesis methods.

<b>Meta-study</b>	<b>Land uses or land use change processes included</b>	<b>Specific impact</b>	<b>Regional coverage</b>	<b>Studies</b>	<b>Observations</b>	<b>Synthesis method*</b>
<b>Agriculture</b>						
Aguilera et al. (2013)	Recommended management practices of Mediterranean cropland	Changes in soil organic carbon and carbon sequestration	Mediterranean regions	79	174	MAES
Govaerts et al. (2009)	Conventional agricultural and conservation agriculture	Carbon sequestration and soil organic carbon	Global	40	127	CSC
Huang et al. (2011)	Various rice cropping systems	Soil organic carbon stocks in paddy fields	China	44	44	MAES
Jarecki and Lal (2003)	Recommended management practices for cropland	Soil organic matter concentration	Global	41	430	VOMA
MacDonald et al. (2012)	Abandoned and remaining agricultural areas	Changes in soil phosphorous	Global	94	94	MAES
Ogle et al. (2005)	Long-term cultivation, setting-aside land, changing tillage management, and varying cropping practices	Change in soil organic carbon	Global	126	126	MAES
Ogle et al. (2012)	Tillage or no-tillage in land management	Change in soil carbon stock and crop productivity	North America	74	1040	MAES
Skinner et al. (2014)	Organic and non-organic agricultural management	Greenhouse gas fluxes	Global	19	25	VOMA
Tonitto et al. (2006)	Conventional inorganic fertilization and diversified land management	Yields, nitrate leaching, and soil nitrates	North America	31	635	MAES
Tuomisto et al. (2012)	Organic farming and conventional farming	Soil organic matter, nutrient losses, eutrophication per unit area and per unit product	Europe	71	257	MAES
<b>Forests</b>						
Bárcena et al. (2014)	Afforestation	Soil organic carbon changes	Northern Europe	18	119	MAES
Berthrong et al. (2009)	Afforestation	Mineral soil quality, including pH, sodium, exchangeable cations, organic carbon, and nitrogen	Global	71	153	MAES
Bonner et al. (2013)	Secondary forests and plantations	Aboveground biomass accumulation	Tropics	48	330	MAES
Cook et al. (2011)	Garden management (fertilization, mowing, irrigation)	Wide range of ecological properties and functions	North America	256	256	VOMA
Hergoualc'h and Verchot (2012)	Deforestation of peat swamp forests	Changes in peat methane fluxes	SE Asia	6	16	CSC
Hoogmoed et al. (2012)	Afforestation of pastures	Soil carbon, soil nitrogen and C:N ratio	Australia	7	25	VOMA
Kauffman et al.	Deforestation and secondary forest	Carbon pools and carbon accumulation	Latin America	7	13	CSC

(2009)	establishment					
Lawrence et al. (2010)	Biomass recovery in shifting cultivation cycles	Biomass recovery after cultivation	Global	6	31	CSC
Li et al. (2012)	Afforestation of cropland and pastures	Dynamics of soil C and N stocks	Global	70	292	CSMDA
Liao et al. (2012)	Plantation forests and natural forests	Soil properties and nutrients	Global	73	560	MAES
Marín-Spiotta and Sharma (2013)	Plantation, secondary and reference forests	Soil carbon	Tropics	81	510	MAES
Putz et al. (2012)	Forest harvesting	Capacity to sustain timber production, retain species, and conserve carbon stocks	Tropics	109	109	CSMDA
Shi et al. (2013)	Afforestation of grasslands and croplands	Deep soil organic carbon	Global	56	63	MAES
van Kooten et al. (2004)	Forest conservation, tree planting and agroforestry	Costs for carbon sequestration	Global	55	981	CSMDA
Zhou et al. (2013)	Partial cutting	Carbon in aboveground biomass, understory, forest floor and soil	Global	81	748	MAES
<b>Multiple land uses</b>						
Don et al. (2011)	Conversion of forests and afforestation	Soil organic carbon stocks	Tropics	153	385	MAES
Guo and Gifford (2002)	Various land use changes	Soil carbon stocks	Global	74	537	MAES
Kim et al. (2013)	Agricultural and natural lands	Background nitrous oxide emissions	Global	362	907	MAES
Lu et al. (2008)	Various land cover types	Red soil rehabilitation	China	55	128	MAES
Poeplau et al. (2011)	Several different land use change types	Soil organic carbon dynamics	Global	95	322	MAES
Powers et al. (2011)	Several different land use change types	Change in soil carbon stock	Tropics	80	837	MAES
Wright and Fridley (2010)	Old field succession	Biomass accumulation	North America	30	30	CSMDA
Ziegler et al. (2012)	Change from swidden to other land use	Carbon emission and sequestration	SE Asia	250	250	CSC

**Table S4:** Meta-studies analyzing the impacts of different land uses or land use change processes on hydrology or water quality.

<b>Meta-study</b>	<b>Land uses or land use change processes included</b>	<b>Specific impact</b>	<b>Regional coverage</b>	<b>Studies</b>	<b>Observations</b>	<b>Synthesis method*</b>
<b>Agriculture</b>						
Ilstedt et al. (2007)	Afforestation and tree planting in agriculture	Water infiltration	Tropics	4	14	MAES
Keatley et al. (2011)	Expansion and intensification of agricultural land	Freshwater eutrophication	Global	67	67	CSMDA
Taranu and Gregory-Eaves	Proportion of agricultural land in a catchment	Lake trophic state	Global	12	358	CSC

(2008)						
<b>Forests</b>						
Farley et al. (2005)	Afforestation, original vegetation type, plantation species, and plantation age	Annual runoff and low flow	Global	20	504	CSDA
Richardson and Béraud (2014)	Logging of riparian forest sites	Water chemistry, algae, organic particles in the water, benthic invertebrates and aquatic insects	Global	18	96	MAES
Salemi et al. (2012)	(Removal of) riparian forests	Water yield and variation	Global	7	10	VOMA
<b>Urban</b>						
Schueler et al. (2009)	Proportion of impervious surface in a watershed	Water quality, biological diversity, geomorphology, hydrology	North America	65	65	COMA
<b>Multiple land uses</b>						
Das et al. (2009)	Land use composition in a watershed	Concentrations of Fe, Mn, Cu, dissolved organic matter	Global	30	135	MAES
Kim and Jackson (2012)	Distribution of main land use types and vegetation cover	Groundwater recharge response	Global	206	600	CSC
Maetens et al. (2012)	Wide range of land cover types, including construction, bare, cropland, grassland and (semi-) natural	Annual runoff, annual runoff coefficient and annual soil loss	Europe and Mediterranean	10	227	CSMDA
Petheram et al. (2002)	Vegetation cover (annual, perennial, trees) in a watershed	Groundwater recharge response	Australia	41	41	VOMA
Scanlon et al. (2006)	Climate variability and vegetation cover change	Groundwater recharge response	Global	140	140	CSC
Smucker and Detenbeck (2014)	Out-of-stream restoration practices, including wetland creation, riparian vegetation and stormwater ponds	Various ecosystem attributes, including	Global	38	319	MAES
Srinivasan et al. (2012)	Agricultural and urban water demand,	Various effects of water quantity on human wellbeing	Global	22	22	COMA
Wickham et al. (2008)	Land use distribution in a watershed	Watershed nutrient yield	North America	167 (sites)	1228	CSDA

**Table S5:** Meta-studies analyzing the impacts of different land uses or land use change processes on food production.

Meta-study	Land uses or land use change processes included	Specific impact	Regional coverage	Studies	Observations	Synthesis method*
<b>Agriculture</b>						
Brouder and Gomez-Macpherson	Conventional and conservation smallholder agriculture	Crop yield for maize, rice, cowpea and sorghum	Subsahara Africa and South Asia	53	56	VOMA

(2014)	Iverson et al.	Different crop rotation schemes	Trade-off between crop yield and biodiversity	Global	26	301	VOMA
(2014)	Ponisio et al.	Conventional and organic agriculture	Crop yields for various crop types	Global	115	1071	MAES
(2014)	De Ponti et al.	Conventional and organic agriculture	Crop yields for various crop types	Global	135	362	VOMA
(2012)	Seufert et al.	Conventional and organic agriculture	Crop yields for various crop types	Global	62	316	MAES
(2012)	Rivest et al.	Scattered trees on pastures	Pasture yield	Global	27	73	MAES
(2013)	Rusinamhodzi et al.	Conventional and conservation agriculture	Maize grain yields	Southern Africa	26	26	VOMA
(2011)							

**Table S6:** Meta-studies analyzing the impacts of different land uses or land use change processes on livelihoods and other socio-economic factors.

Meta-study	Land uses or land use change processes included	Specific impact	Regional coverage	Studies	Observations	Synthesis method*
<b>Agriculture</b>						
Bennett and Franzel (2013)	Organic and resource conserving, and conventional agriculture	Livelihoods: yields, food security, income	Tropics	31	31	COMA
van Vliet et al. (2013)	Changes in cropland area	Environmental and livelihood impacts of cropland changes	Sahel	25	50	VOMA
<b>Grassland</b>						
Muchena et al. (2005)	Land degradation	Consequences for food security and rural livelihoods	Africa	14	21	CSC
<b>Multiple land uses</b>						
Cramb et al. (2009)	Intensification and extensification of swidden	Economic and cultural consequences of changes in swidden	SE Asia	6	6	CSC

\* Synthesis methods: cross-site comparisons (CSC) are syntheses of unsystematically selected cases studies; cross-site data analyses (CSDA) are statistical analyses identifying patterns across aggregate variable data; cross-site meta-data analyses (CSMDA) and meta-analyses of effect sizes (MAES) are statistical analyses (e.g. regression) across data values and the magnitudes of effects reported in systematically selected case studies respectively; variable-oriented meta-analyses (VOMA) are statistical analyses identifying links between coded variables across cases; and case-oriented meta-analyses (COMA) are analyses of the relationships between coded variables within and across cases. For a more elaborate description of these methods, see (Magliocca et al. 2015)

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