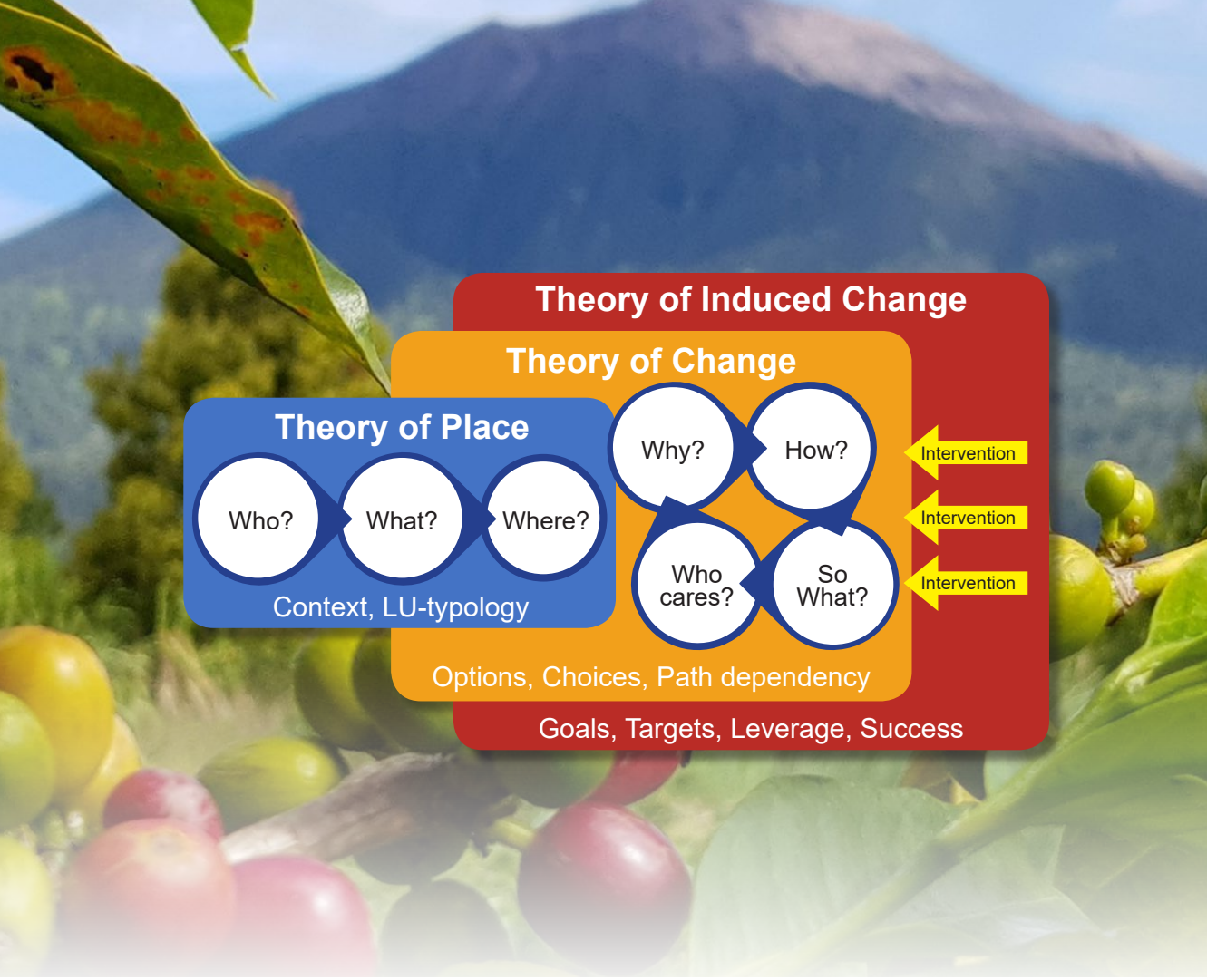

Theories of place, change and induced change for tree-crop-based agroforestry

Meine van Noordwijk

World Agroforestry

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2021

Synopsis/abstract

Agroforestry with a strong market-oriented component of tree crops but also supporting local agroecosystem functions can be analysed and understood in multiple ways, building on many disciplinary traditions and using their terminology and concepts. Characterization of context and choices, plus understanding relationships and feedbacks is essential for appreciating 'options in context' and the way these change over time. Beyond observer roles, active engagement as agent of induced change to help make the world a better place has since long been the ambition of advocates of agroforestry. As a background to such endeavours , this publication introduces more than one hundred aspects, visually and with a short text, providing references to more specialized literature. Aspects include: A) Characterization of structure in existing land use can lead to a Theory of Place (ToP: patterns answering what?, where?, who? questions), B) Diagnosis of functions influenced by changing practices and systems can lead to a Theory of Change (ToC: patterns in answering how?, why?, since when?, so what? and who cares?), C) Assessments of leverage points for adaptive, transformative and re-imaginative change can lead to a project-design Theory of Induced Change (ToIC), D) Research methods for ecological, agronomic, social, economic and policy-oriented research require clarity on units of analysis and scale relations of observable properties in relation to questions and hypotheses, E) Guidance on how research methods need to match the stage of public issue cycle debate to contribute to policy reform.

Acknowledgements

The work reflected here has been a collaborative effort to understand a wide range of perspectives, in which the intellectual contributions of numerous colleagues can be recognized for those who have been part of the process. The author acknowledged stimulating discussions and sometimes fierce debates with too many people to mention here individually. Authorship of the many papers referenced gives an indication of the largest debts.

Contents

Introduction 1
1.1 Use-oriented fundamental science 2
1.2 Agroforestry 2
1.3 Seventeen Sustainable Development Goals 3
1.4 Agroforestry as part of social-ecological systems 3
1.5 Social-ecological systems (SES) 4
1.6 Theories of place, change, and induced change 4
1.7 Forest transition theory 5
1.8 Scale matters 6
1.9 Five types of asset or capital 6
1.10 Leverage points 7
1.11 Land use as integrated policy agenda 7
1.12 Anthropocene challenges 8

The Who? What? Where? of land use as Theory of Place (ToP) 9
2.1 Ecological Science-based perspectives on landscapes as part of a ToP 9
2.1.1 Participatory Landscape Appraisal 9
2.1.2 Geology 9
2.1.3 Land forms 10
2.1.4 Hydroclimatic zones 10
2.1.5 Natural vegetation 11
2.1.6 The water balance at 'patch' scale 11
2.1.7 River flow Q links climate, vegetation and soils 12
2.1.8 Climate suitability for tree crops 12
2.1.9 Biodiversity and its 'hot spots' 13
2.1.10 Tree-site matching 13
2.1.11 Plot-level sampling of vegetation 14
2.1.12 Pollination and dispersal modes 14
2.1.13 Wood density 15
2.1.14 Allometrics: scaling rules for biomass 15
2.1.16 'Stock difference' 16
2.1.17 Biodiversity versus C stocks 17
2.1.18 Pedotransfer functions 17
2.1.19 Microclimate 18
2.1.20 Tree cover impacts on hydrology 18
2.1.21 Tree crop yields vs tree cover 19
2.1.22 Biodiversity indicators 19
2.1.23 Yield gaps 20
2.1.24 the Land Equivalent Ratio (LER) 20
2.1.25 Land use intensity 21
2.1.26 Minimizing the 'footprint' 21
2.1.27 Cyclical vs internal rejuvenation ('sisipan') 22
2.1.28 Landscape-scale intensification 22
2.2 Social and policy perspectives on land and landscapes as part of a ToP 23
2.2.1 Land cover vs land use vs land use rights 23
2.2.2 Forests vs Tree cover 23
2.2.3 Tree cover in agricultural lands 24
2.2.4 Land cover typology 24
2.2.6 Agroforestry categories 24

2.2.7 Evolving tree crop production systems 25
2.2.8 Permitted land uses 25
2.2.9 Supply chains 26
2.2.11 Economic geography 27
2.2.12 Global trade source dependence 27
2.2.13 Water conflicts 28
2.2.14 Taxing tree plantations for their green water use 28
2.2.15 Buffer and filters 29
2.3 Social stratification as part of Theories of Place 29
2.3.1 Bundles of rights 29
2.3.2 Stratified property rights 30
2.3.3 Indigenous people self-identifying as historical right owners 30
2.3.4 Migration decisions 31
2.3.5 Migrants as stakeholders 31
2.3.6 Gender analysis 32
2.3.7 Gender perspectives in selecting tree species 32
2.3.8 Youth and intergenerational issues. 33
2.3.9 WhyNoTree analysis of local constraints to tree presence 33
2.3.10 Land use profitability analysis 34
2.3.11 Labour accounting 34
2.3.12 Land quality change. 35
2.3.13 The diversity of Local ecological knowledge 35
2.3.14 The scope of local ecological knowledge 36
2.3.15 Human relationship with Nature 36
2.3.16 Human vulnerability 37

The So what?, Who cares?, and Why? of a theory of change (ToC) 38
3.1 Theories of Change (ToC) 38
3.2 Power differences 38
3.3 Land Use drivers as explanatory factors 39
3.4 Chronosequence pitfalls 39
3.5 Economic demo/geography 40
3.6 Institutions 40
3.7 Hydrological impacts 41
3.8 Water management 41
3.9 Local monitoring, citizen science 42
3.10 Tradeoff analysis in 4 steps 42
3.11 Internalizing externalities 43
3.12 The Maslow pyramid 43
3.13 Five ways of knowing that jointly can change social-ecological systems 44
3.14 Three paradigms within the ‘ payments for ecosystem services’ (PES) umbrella 44
3.15 Biodiversity paradox 45
3.16 Combining PES paradigms across scales 45
3.17 Instrumental (goal-oriented) and relational values 46
3.18 Valuation as a means of communication 46
3.19 Three forest-water paradigms shape policy responses 47
3.20 Ecosystem Services typologies 47
3.21 HANPP: human appropriation of net primary productivity 48
3.22 The land sparing/sharing debate 48
3.23 Pathways for tree crop rejuvenation reach across scales 49

3.24 Addressing root causes, the common stem and the diversified canopy 49
3.25 Policy questions in reducing deforestation 50

Leverage points for a Theory of Induced Change 51
4.1 The issue attention cycle 51
4.2 Leverage points for a Theory of Induced Change (TolC) 51
4.3 A combined typology of knowledge and action 52
4.4 Negotiation Support Systems (NSS) 52
4.5 Understanding a 'policy-mix' 53
4.6 Five scales of economic analysis 53
4.7 The doughnut challenge 54
4.8 Boundary work 54
4.9 Ecological and Social aspects across seven landscape issues 55
4.10 Reconciling 'top-down'; and 'bottom-up' 55
4.11 A map of 18 pathways to the eradication of extreme poverty 56
4.12 Capital interactions model of national policy options 56
4.13 Restoration intensity 57
4.14 Tree crops as part of the land restoration debate 57
4.15 Certification 58
4.16 The common Rio agenda 58
4.17 Reducing emissions from all land uses (REALU) 59
4.18 Land-use effects on hydro-climate 59
4.19 Zero-deforestation commitments 60
4.20 Living-wage commitments 60
4.21 A proposed global deal for Nature 61
4.22 The agenda for the Anthropocene 61

Discussion 62

References 67

1

Introduction

A forthcoming book on tree crops focussed on Africa presents ideas, experience and perspectives on tree crop commodities and their relationship with agroforestry, presented from a range of disciplinary backgrounds. Each of these tends to have its own traditions of concepts, terminology, typologies and research methods, which the reader may not be familiar with, but that the text will not be able to fully explain. Starting as a glossary for that book, the current text grew into a stand-alone publication that may have wider utility. It deals with 'zooming in' and 'zooming out', dealing with details and the bigger picture. As the human mind is limited in its capacity to do this simultaneously, it spreads the perspectives over multiple pages, parsimonious with words, rich in coloured brain map diagrams.

Some words are used with multiple meanings, other times essentially the same thing is called by different names. In this collection we try to give an overview of the many ways the issues at stake have been conceptualized and contextualized, providing references for further reading or methodological guidance. This first chapter introduces some of the basic interdisciplinary concepts that may help in bridging between different types of knowledge, through what is sometimes known as 'boundary work'. Typically, in competition for attention and sometimes funding, many claim to have the key…

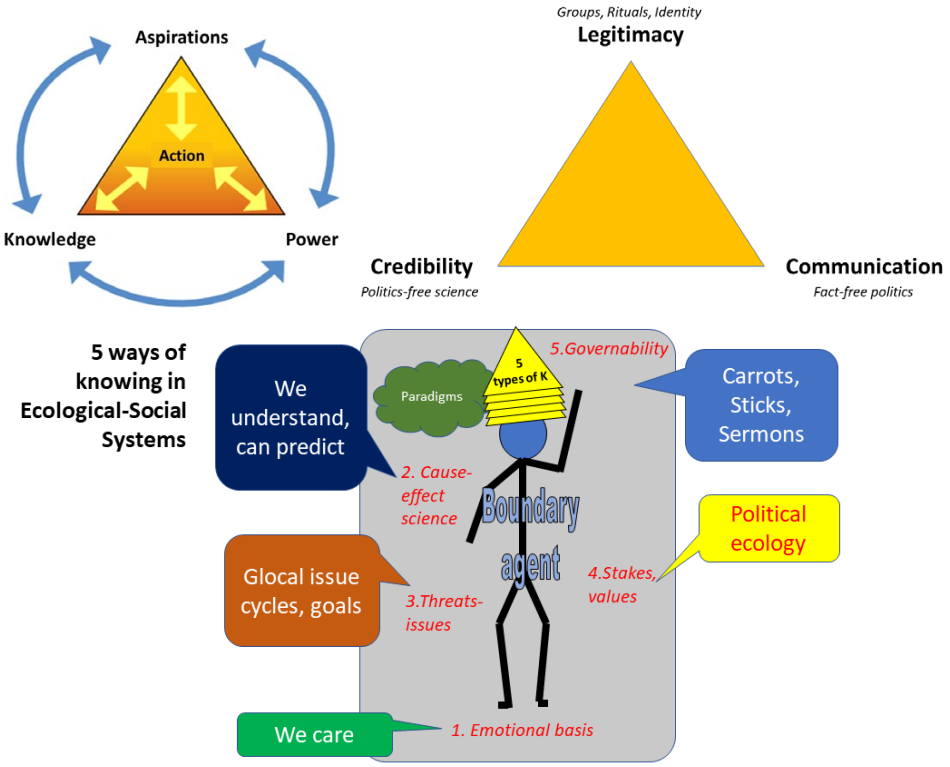
Many claim to have the key

...until they realize what the sealed door is like.

Interdisciplinary interactions sometimes reminds one of the old man looking for a lost key under a streetlamp, "Did you lose your key here?", "No, but here I at least have light to see anything". We all do what we have been trained to do – not necessarily what is the most relevant to do.

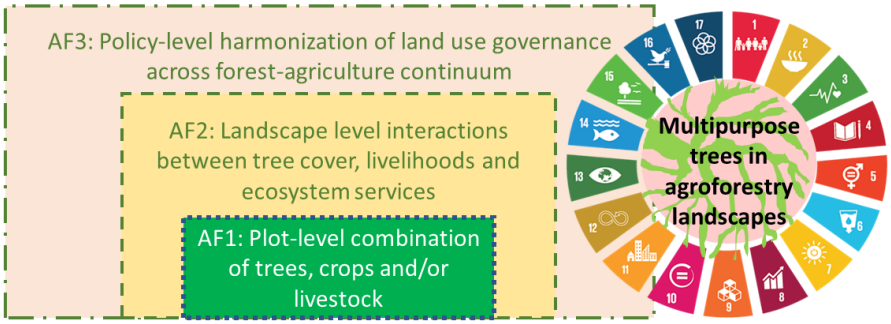
1.1 Use-oriented fundamental science

… does not compromise on the 'credibility' standards of science, but balances these with action-oriented salience and stakeholder legitimacy, acknowledging power and aspirations.[1]



1.2 Agroforestry

… is now understood as a concept that applies at plot/farm (AF1), landscape (AF2) and governance (AF3) level; all interfacing agriculture and forestry, reflecting the origin of the term.[2]



1.3 Seventeen Sustainable Development Goals

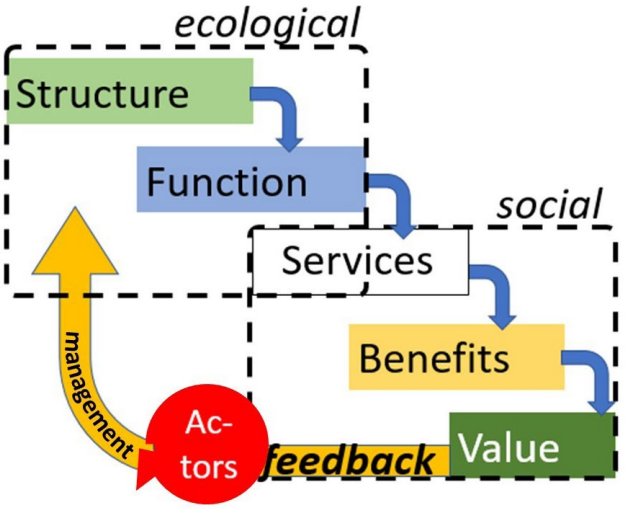
… require integrated answers and approaches.[3]

1.4 Agroforestry as part of social-ecological systems

We're building on strong foundations that positioned agroforestry in the literature on social-ecological systems and as landscape approaches.[1,4,5,6]

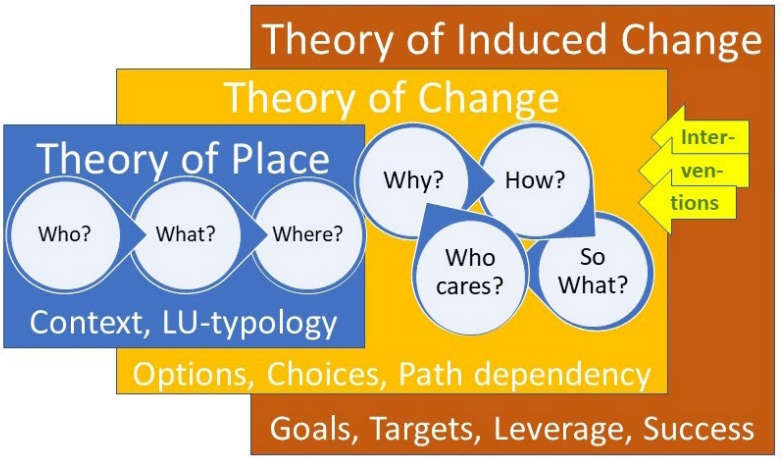
1.5 Social-ecological systems (SES)

An SES approach aims to understand interactions between structure, function, services, benefits, value, decisions, and management in a 'cascade' model, with feedback.[3,7]



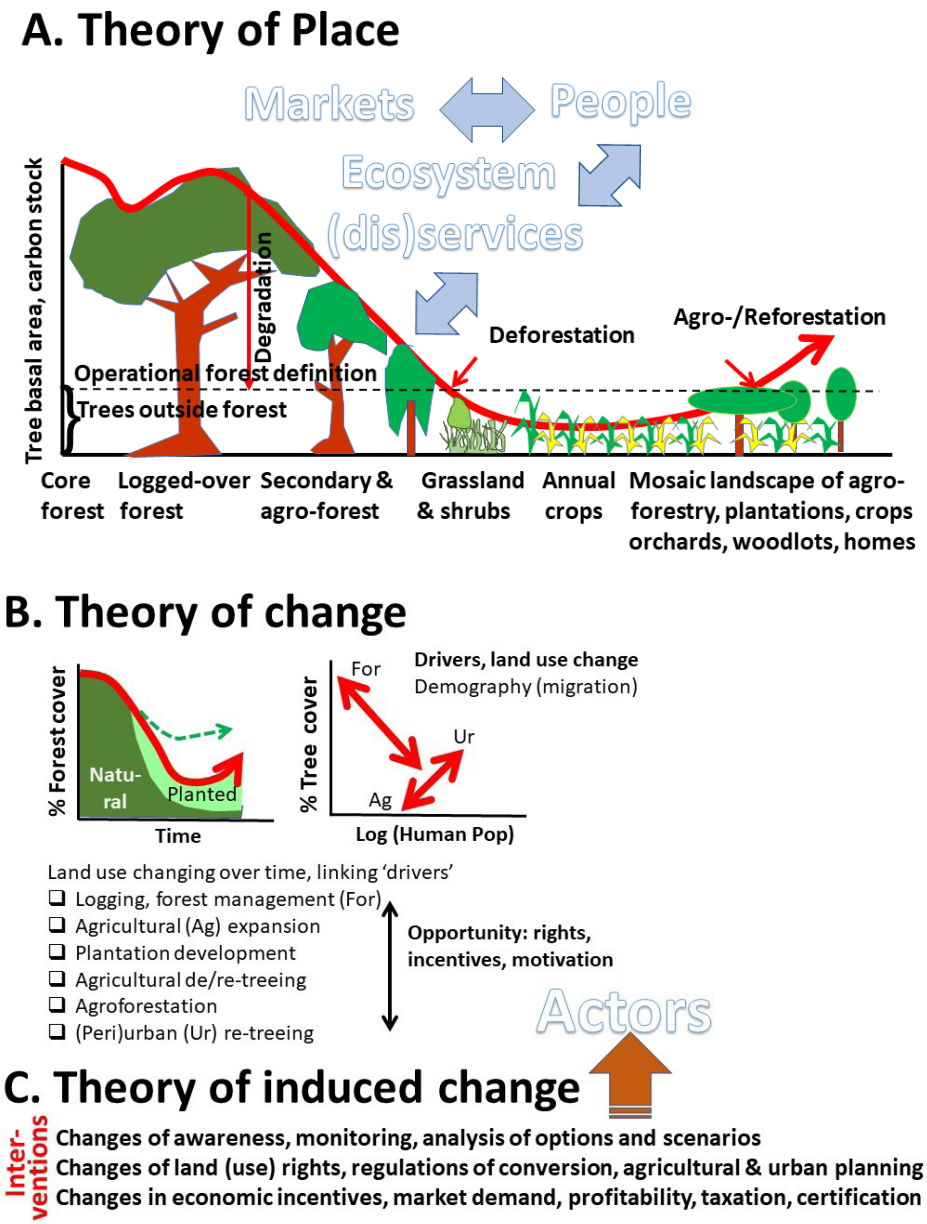
1.6 Theories of place, change, and induced change

Who?, what?, where? as the basic questions of a Theory of Place (ToP) form the basis for understanding dynamics of land use in Theories of Change (ToC), that are an essential building block for Theories of Induced Change (ToIC), that focus on bringing Goals into reach by targeted interventions.[8,9]



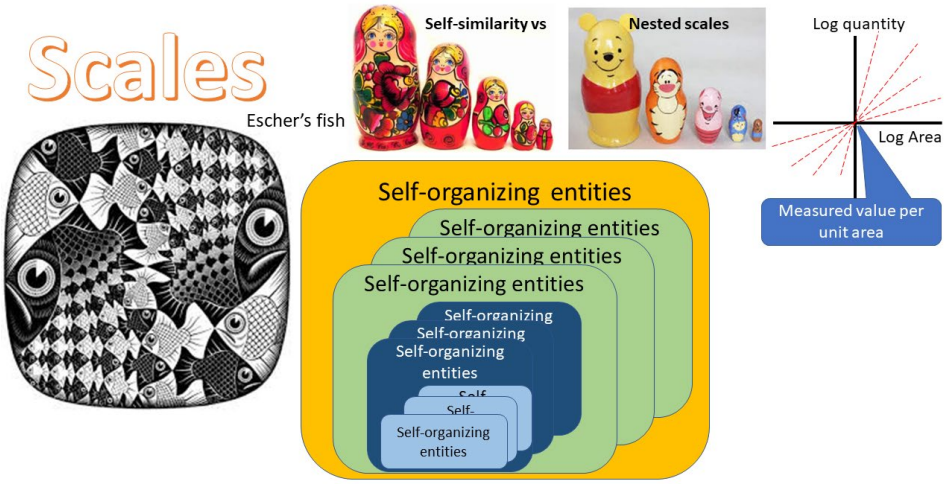
1.7 Forest transition theory

… describes a ToP, a ToC and can be used as a ToIC.[10]



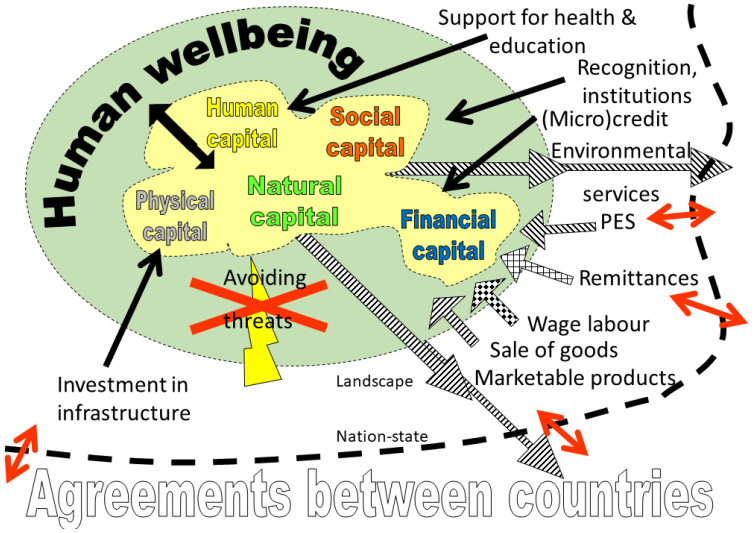
1.8 Scale matters

Scaling matters, as the simple assumption that ‘area’ is a default scaling rule often isn’t true.[11] Two matroeschka-doll-set demonstrate two perspectives on scaling: homogeneous and role-differentiated.



1.9 Five types of asset or capital

… are used in the production of goods and services, depleting or increasing capitals at different rates. It can be seen as converting one type of capital (e.g. natural) into another (e.g. human or infrastuctural); conversion typifies scale transitions to national and global scale.[12]



1.10 Leverage points

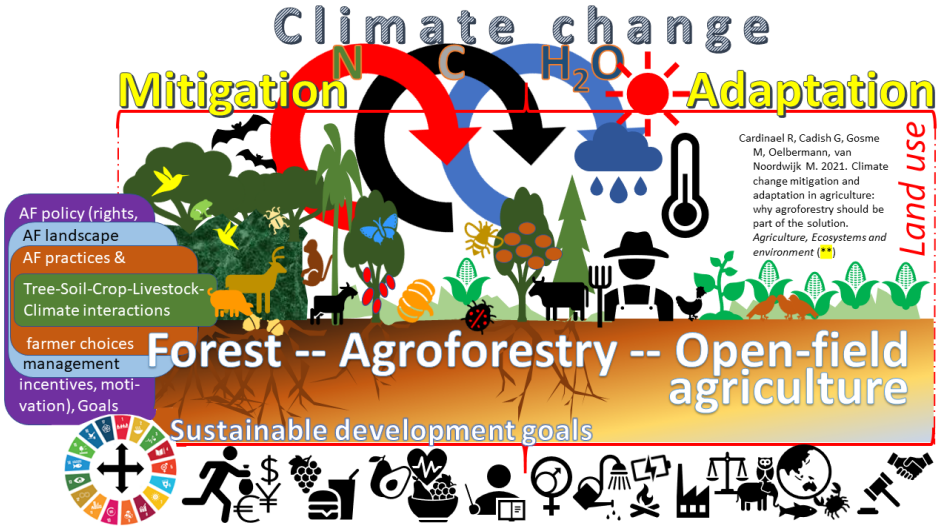
… to intervene in systems according to Donna Meadows.[13]

Twelve places to intervene in a system (in increasing order of effectiveness in changing its dynamic properties)

12. Constants, parameters, numbers (such as subsidies, taxes, standards, data)	***Inventories, Theories of Place***
11. Sizes of buffers and stabilizing stocks relative to associated flows 10. Structure of material stocks and flows (such as transport networks, population age structure) 9. Lag times and time of delays, relative to the rate of system change 8. Strength of negative feedback loops, relative to the impacts they are trying to correct against 7. The gain around driving positive feedback loops 6. The structure of information flows (who does and does not have access to what kinds of information)	***Dynamics, Theories of Change***
5. The rules of the system (such as incentives, punishments, constraints) 4. The power to add, change, evolve, or self-organize system structure	***Dynamics, Theories of Induced Change***
3. The goals of the system 2. The mindset or paradigm out of which the system (with its goals, structure, rules, delays, feedbacks and parameters) arises 1. The power to transcend paradigms	

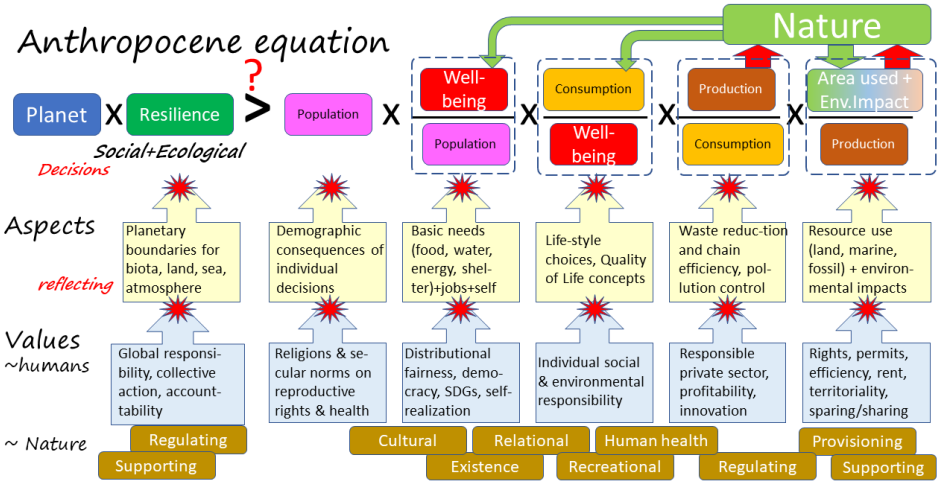
1.11 Land use as integrated policy agenda

Land use (including forests, agroforestry and open-field agriculture) intermediates between climate and the achievement of Sustainable Devlopment Goals; interaction of land use with the climate change mitigation goals is primarily based on the carbon and nitrogen cycles between atmosphere and terrestrial systems, interaction with the adaptation agenda through the hydrological cycle and temperature, but as these ecological interactions are closely linked, so are the mitigation and adaptation agenda.[14]



1.12 Anthropocene challenges

There are limited degrees of freedom in matching the increasing aspirations of well-being for a growing population on our planet A: reduced consumption per unit wellbeing, production per unit consumption, and/or environmental damage per unit production.[3]



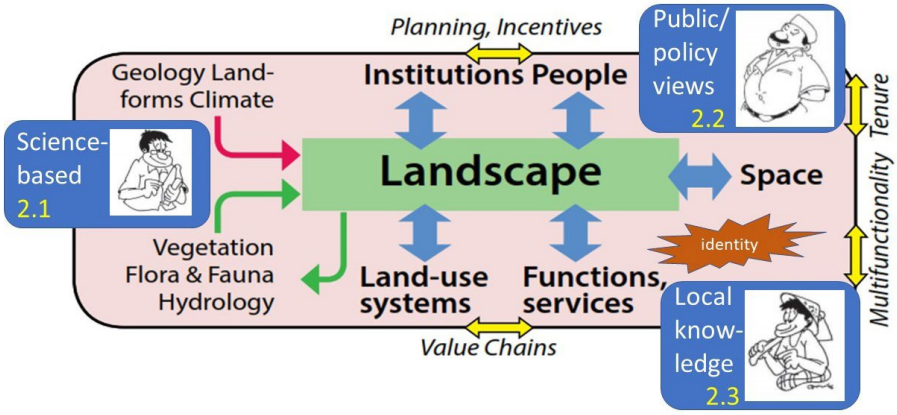
2

The Who? What? Where? of land use as Theory of Place (ToP)

2.1 Ecological Science-based perspectives on landscapes as part of a ToP

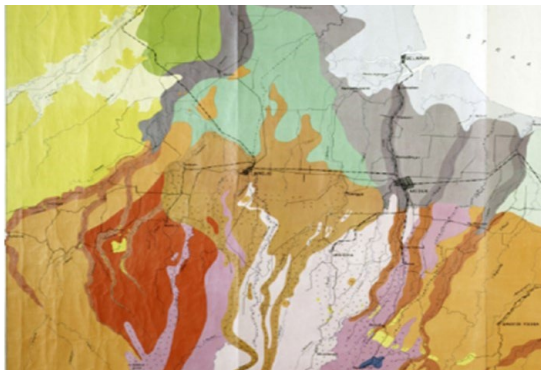
2.1.1 Participatory Landscape Appraisal

... aims to compare, contrast and where possible reconcile three perspectives: one based on local knowledge, a second through the lens of public policies and as a third a science-based view. Landscapes are based on the abiotic background, vegetation, flora and fauna, and are shaped by human modification of land cover in an institutional context, constrained by rights, markets and impacts, providing goods and services.[15]



2.1.2 Geology

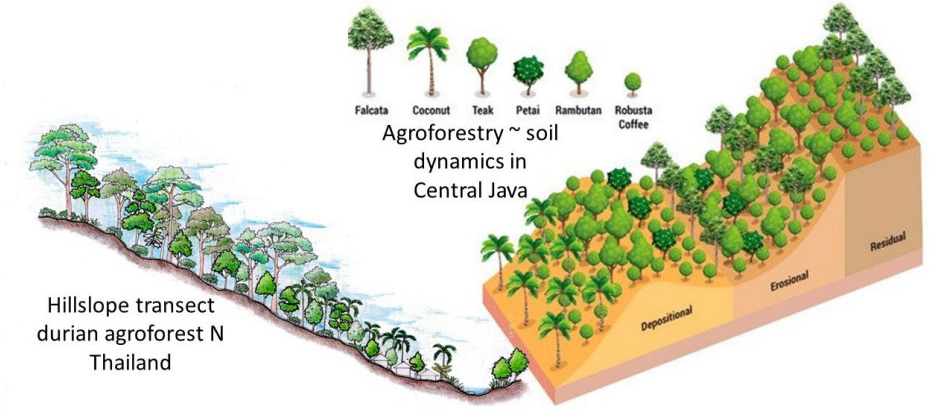
… accounts for the parent material for in-situ soil formation; it may vary over short distances, especially in volcanic landscapes where superimposed lava flows brought material that devel-ops into soils of different fertility. For example, soils of volcanic origin around Toba



(N Sumatra) show recognizable eruption patterns and explain large differences in soil fertility.[16]

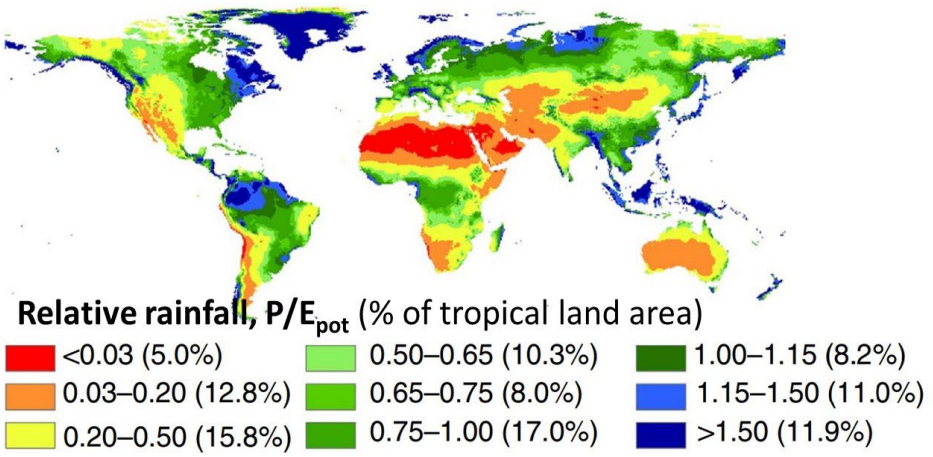
2.1.3 Land forms

Cross-sections from ridge to river ('toposequences') reflect patterns of erosion and deposition (sedi¬mentation), of hills subject to landslides and colluvial material accumulating. Along with variations in soil depth, soil fertility, and groundwater movement, farmers may have found ways to identify the best places for the most demanding (tree) crops.[17]



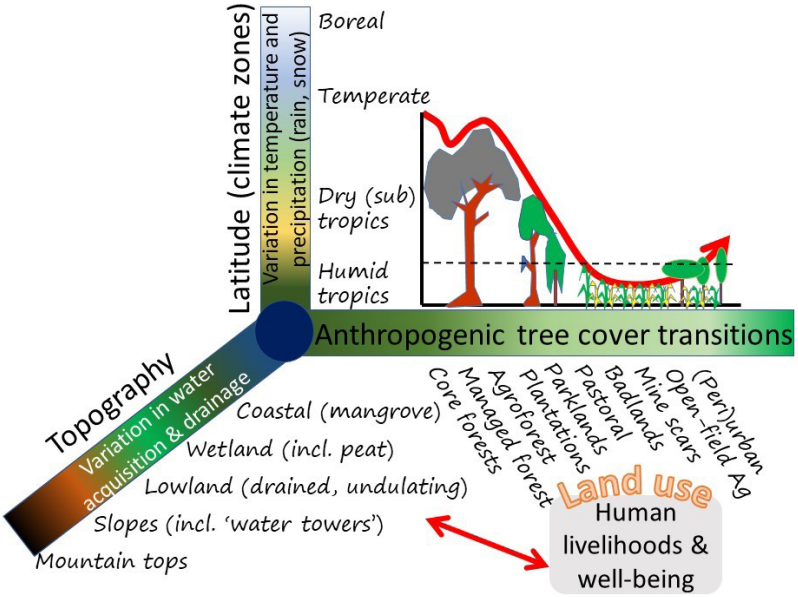
2.1.4 Hydroclimatic zones

… have been defined in multiple ways; a simple one relates to the hydroclimate and compares rainfall (P, or precipitation which can include snow) to the potential rate of evapotranspiration (E_{pot}), both in mm/year.[9]



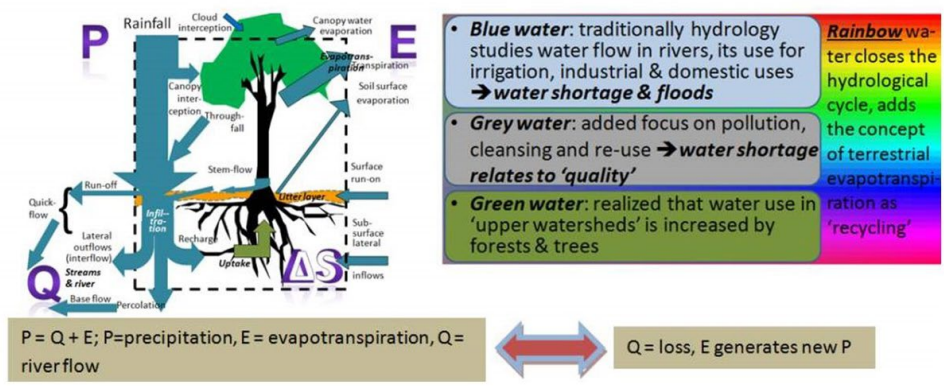
2.1.5 Natural vegetation

… varies with latitude, elevation, topography and is subject to human modification, potentially along a tree cover or forest transition trajectory; vegetation typology can be purely based on vegetation structure, but often incorporates elements of the other determinants.[13]



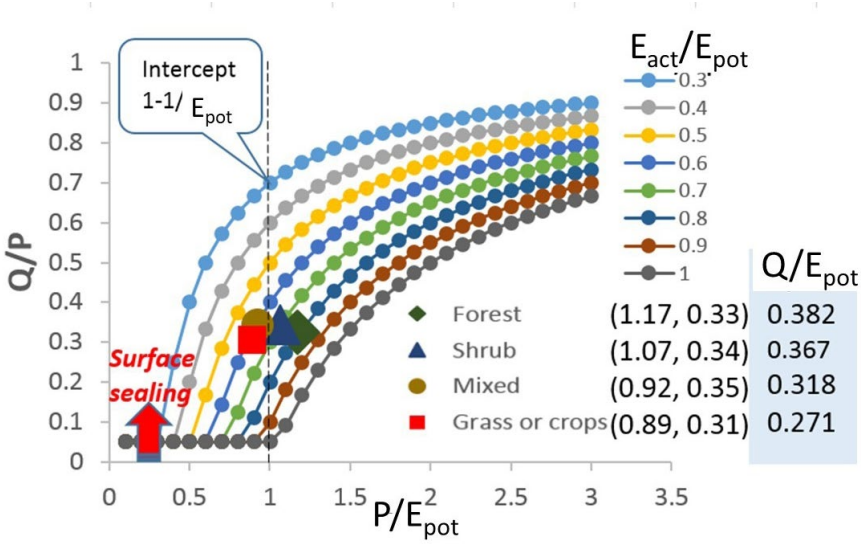
2.1.6 The water balance at 'patch' scale

… forms the basis of landscape and continental water cycles.[18]



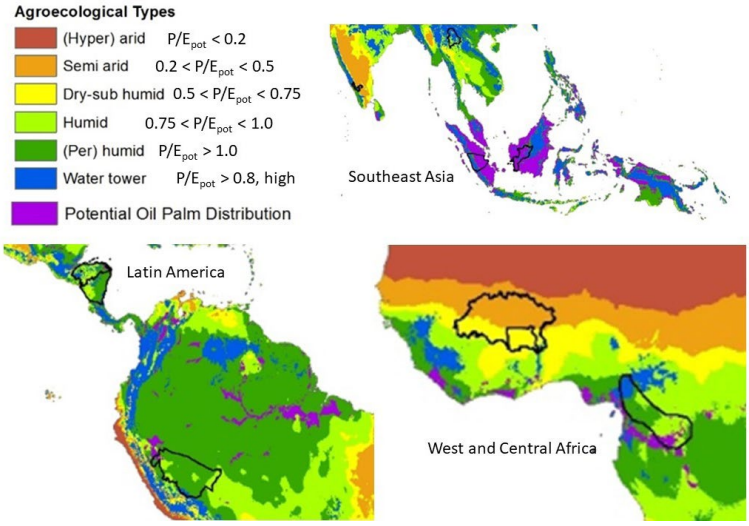
2.1.7 River flow Q links climate, vegetation and soils

… via terms of the water balance (in mm y-1): P = precipitation, E_{pot} = potential evapotranspiration, the E_{act}/E_{pot} ratio that depends on Leaf Area Index, and soil properties that lead to runoff even in dry climates.[19]



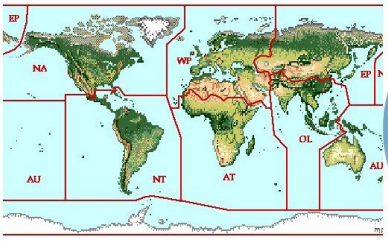
2.1.8 Climate suitability for tree crops

In tropical areas with relatively small differences in temperature, the hydroclimate can be used to assess site suitability for (tree) crops (along with elevation and temperature data); special attention is war-ranted for the water towers that provide water to low-lands, but are attractive for production of coffee, tea, temperate vegetables and dairy, often leading to conflicts with downstream.[9]

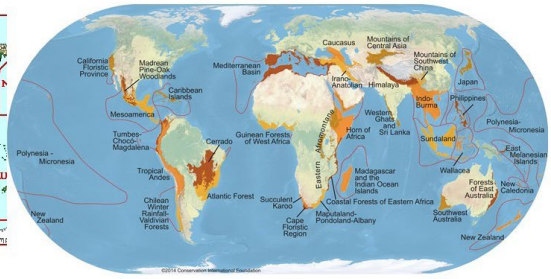


2.1.9 Biodiversity and its 'hot spots'

… reflect first of all the historical patterns of continental connectivity.[20]



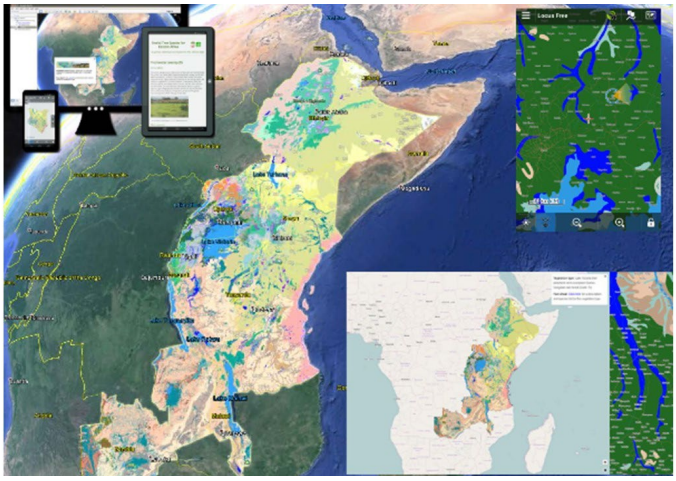
In terms of native flora and fauna, **biogeography** recognizes four tropical regions: NT=Neotropical, AT=Afrotropical, OL=Oriental, and AU=Australasian and three temperate/arctic ones: NA=Nearctic, EP=East Palearctic, WP=West Palearctic



More specific maps of 'biodiversity hotspots' with large numbers of plants and animals not found elsewhere exist in many variants (https://commons.wikimedia.org/wiki/File:Biodiversity_Hotspots_Map.jpg)

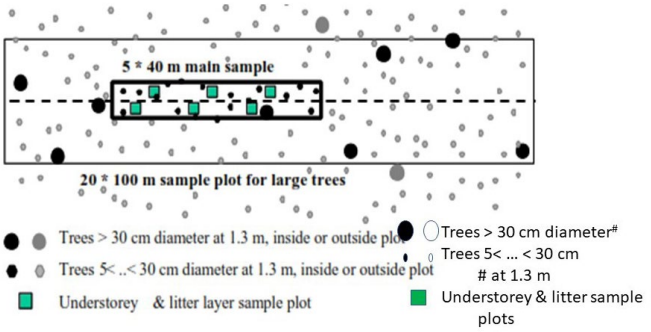
2.1.10 Tree-site matching

… for managed agroforestry landscapes requires clarity on human purpose, ecological requirements of trees, and data on which trees are native to the soil and climate of the site.[21,22]



2.1.11 Plot-level sampling of vegetation

… is the basis of characterizing tree diversity, appraising Carbon stocks and understanding the dynamics of tree life cycles. Required sample size depends on presence of large trees occurring at low densities but with large effect on results.[23]

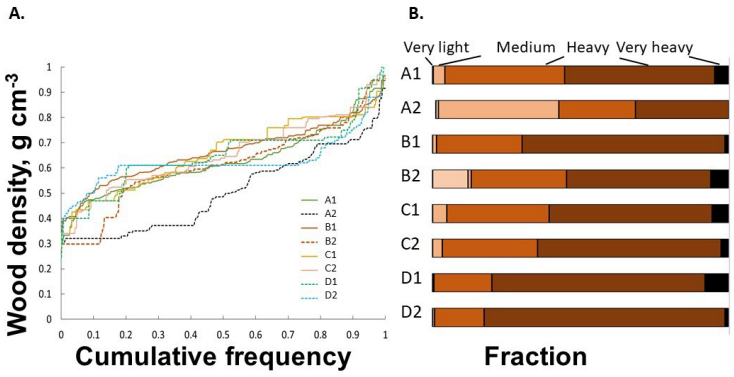


2.1.12 Pollination and dispersal modes

… can be assessed through the botanical identities of trees and helps to characterize, especially in high-diversity vegetation.[24]

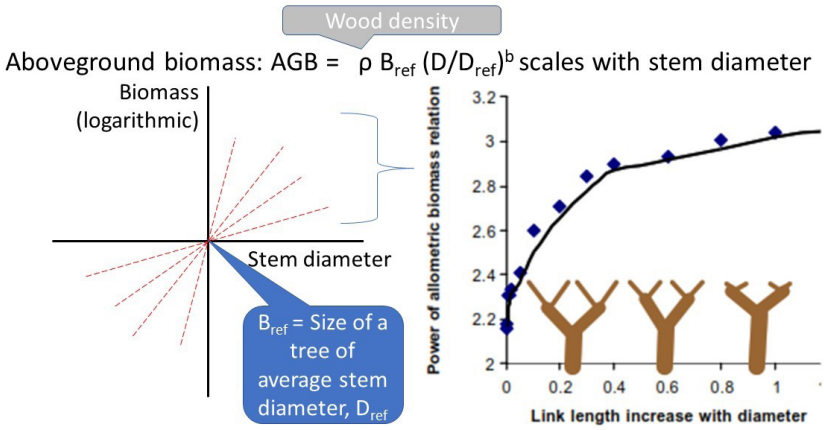
2.1.13 Wood density

… reflects a trade-off between tree growth rate and longevity. Community-level wood density profiles indicate the successional status and renewal within a vegetation.[25]



2.1.14 Allometrics: scaling rules for biomass

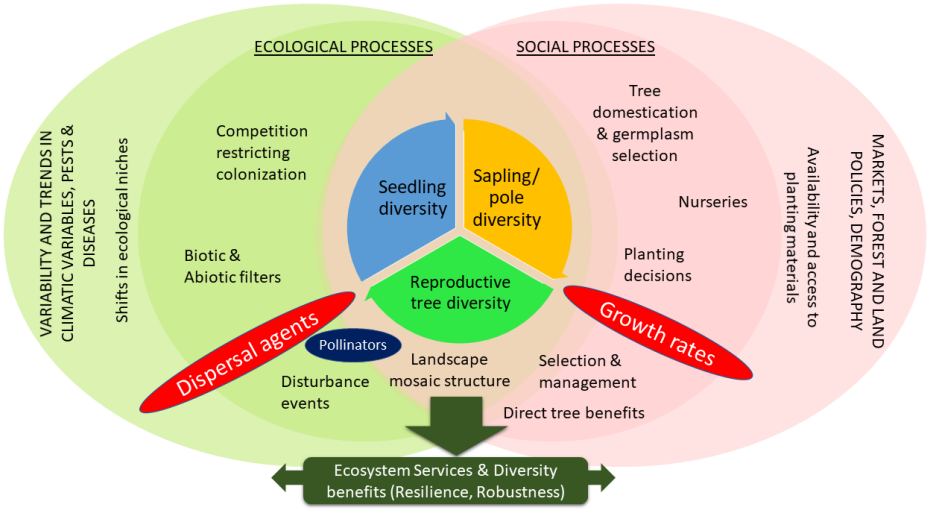
Tree biomass estimates are often based on the easily measured stem diameter, or increasingly for remote sensing applications, canopy diameter. Beyond treating these as 'black box' statistical relationships, they can be understood as consequence of tree architecture, fractal branching rules for transport capacity and biomechanical requirements on stability.[26,27,28,29]



Empirical relations can be understood on the basis of fractal branching rules.

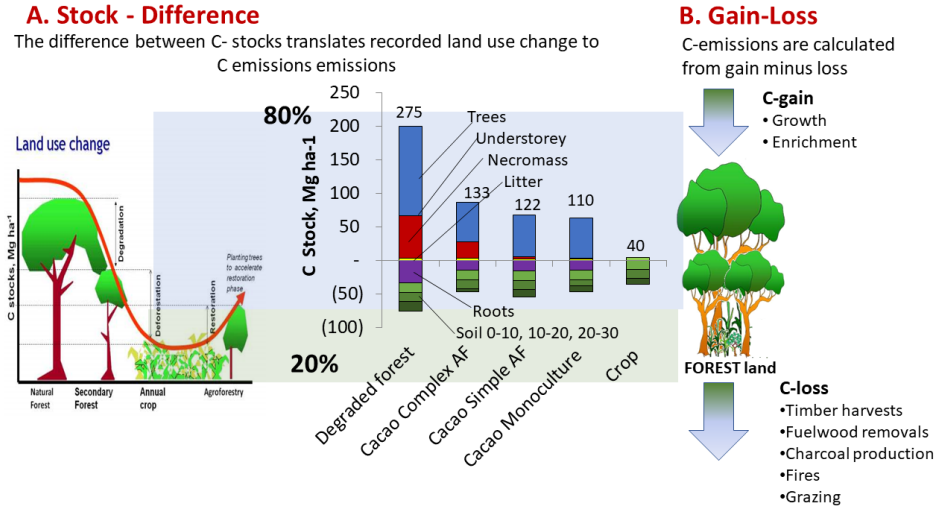
2.1.15 Tree life cycles

Biodiversity depends trees being able to complete their seed – seedling – sapling – pole – tree cycle.[20]



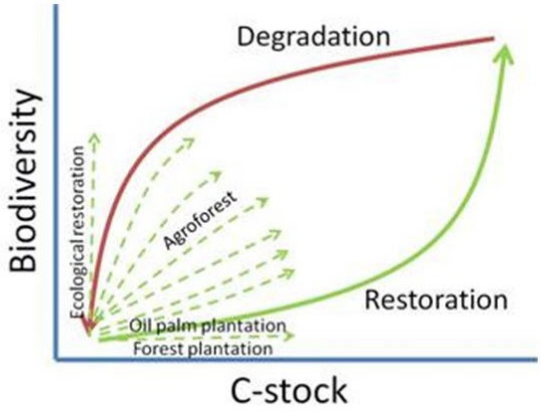
2.1.16 'Stock difference'

… is the simplest carbon emission estimator based on land use change data and time-averaged C stocks of land use classes; more data-demanding approaches use a gain-loss approach.[19]



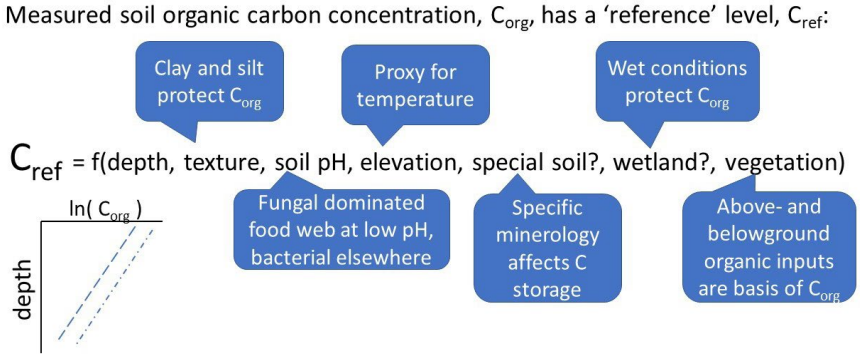
2.1.17 Biodiversity versus C stocks

Plot-level diversity (e.g. of trees) usually correlates with C stocks, but degradation and restoration curves can differ.[30,31]



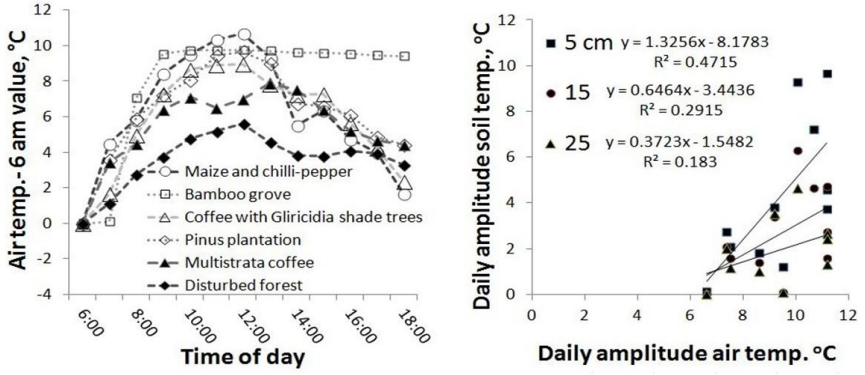
2.1.18 Pedotransfer functions

… provide a reference for expected soil carbon concentrations and help (through C_{org}/C_{ref}) interpret soil data as influenced by land cover (vegetation).[32,33]



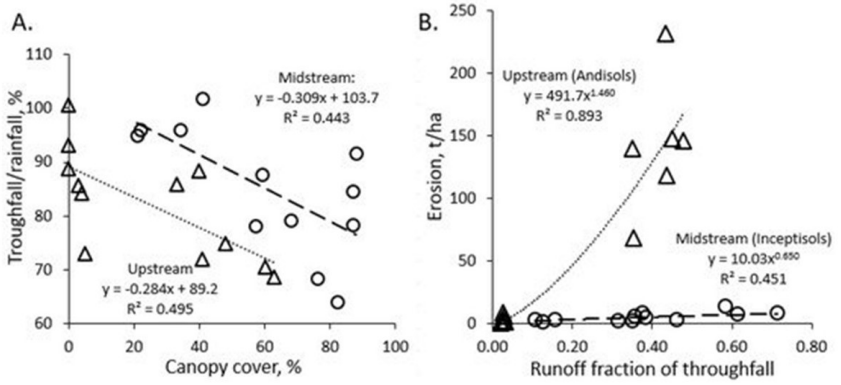
2.1.19 Microclimate

is influenced by tree cover, with effects on air temperature (measured in a shaded box) of 2-4 °C, and reduced fluctuations in soil temperature, depending on ground cover, influencing soil processes.[34]



2.1.20 Tree cover impacts on hydrology

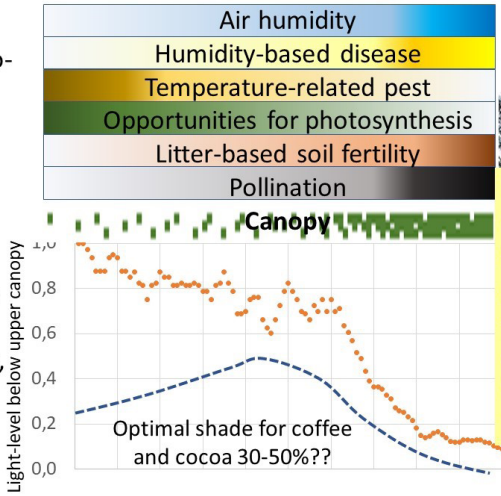
the degree of tree canopy cover that is needed to secure infiltration and reduce overland flow and erosion can vary over short ranges, along with rainfall intensity, tree structure (e.g. drip tips) and soil entrainability.[35]



2.1.21 Tree crop yields vs tree cover

Optimum shade depends on context[36,37], including various pest and disease pressures.

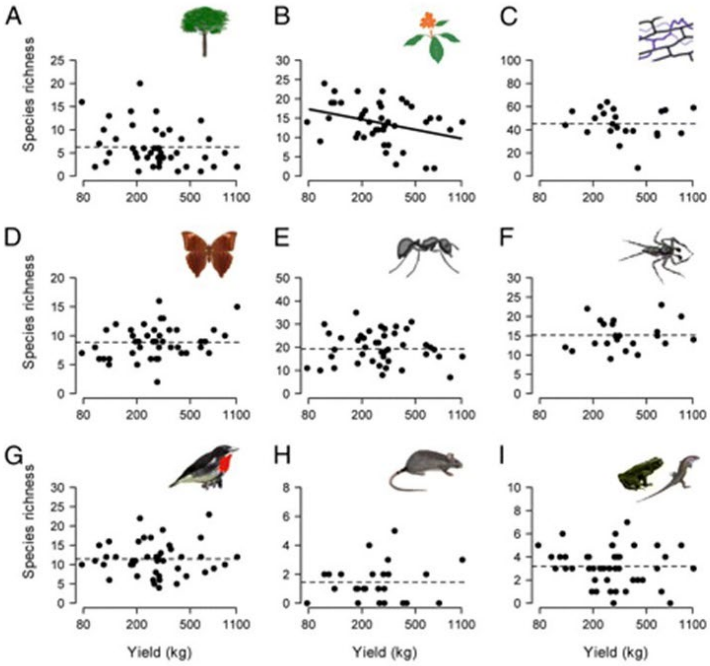
Shading implies changes in photo-synthesis, but also in pest and disease pressu-res, pollination and soil fertility. Net effects de-pend on the tree crop (and its cultivar), climate, soil type and pollinator behaviour.



Shade management depends on spacing, orientation and type of companion trees at strategy level, and options for tactical management by e.g. pruning 'shade trees'

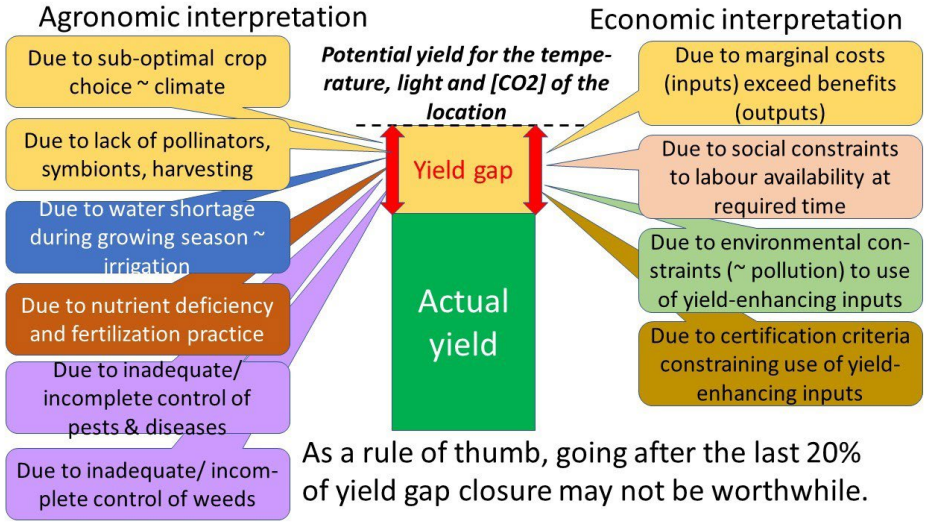
2.1.22 Biodiversity indicators

… in multistrata agroforestry are compatible with relatively high yields; the example is based on cocoa agroforestry data.[38]



2.1.23 Yield gaps

… are defined as the difference between actual and potential yields, expressed in an absolute or relative quantity.[39]



2.1.24 the Land Equivalent Ratio (LER)

… replaces 'yield gap' as key metric for evaluating the land use efficiency of mixed production systems, as it also relates actual to potential yield; however, values above 1.0 suggests 'negative yield gaps.'[40]

If LER_M the "Land Equivalent Ratio for Multifunctionality" exceeds 1.0 the mixed system spares land relative to a segregated mosaic of monofunctional land uses.

$$LER_M = \gamma_P \sum_i P_i / P_{i,ref} + \gamma_R \sum_j R_j / R_{j,ref} + \gamma_C \sum_k C_k / C_{k,ref}$$

Plot-to-landscape scale metric for multifunctional land use

Societal weighting of provisioning services

Current vs reference services per unit land

Societal weighting of regulating services

Current vs reference services per unit land

Societal weighting of cultural services

Current vs reference services per unit land

With

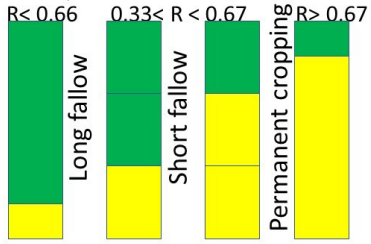
- P_i, R_j and C_k be the attainment (in any metric) of a range of provisioning (P), regulating (R) and Cultural (C) services provided by a landscape
- $P_{i,ref}$, $R_{j,ref}$ and $C_{k,ref}$ be the attainment (in the same metric) of such services in a landscape optimized for that specific service (often a 'monoculture')
- $\gamma_{P,i}$, $\gamma_{R,j}$ and $\gamma_{C,k}$ be a weighting function for the importance of the three groups of ecosystem services

2.1.25 Land use intensity

… needs a quantitative metric before hypotheses on 'intensification' can be tested, and 'ecological intensification' can be defined. Measuring 'intensity' by output leads to circular arguments, it needs to be understood at 'input' level. USD/ha can give some rough indication.[41,42]

Despite the many hypotheses that link positive and/or negative consequences to 'intensification' of land use, there is no agreed metric to characterize intensity.

- Temporal intensity increases

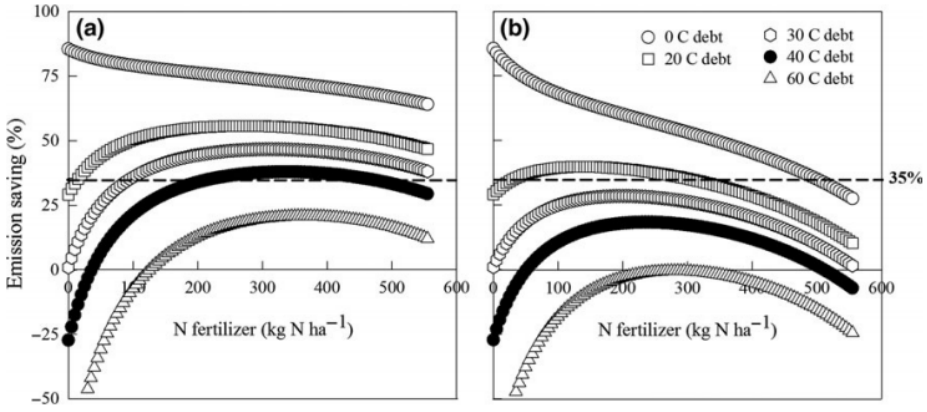


The Ruthenberg R indicates crop/(crop+fallow) duration and distinguishes long from short fallow and 'permanent' cropping. But what if the fallow becomes an agroforest and is economically attractive?

- Labour input (ha.year)$^{-1}$ increases
- Spatial intensity increases
  The fraction of land area maintained in non-directly productive forms of land use decreases
- Labour input is substituted by fossil energy in mechanization?
- Traffic intensity and loads increase inducing soil compaction
- Drainage and irrigation modify the water balance
- External nutrient inputs replace internal recycling
- Use of agrochemicals to control pests, diseases and weeds increases
- Knowledge intensity increases for 'precision farming'

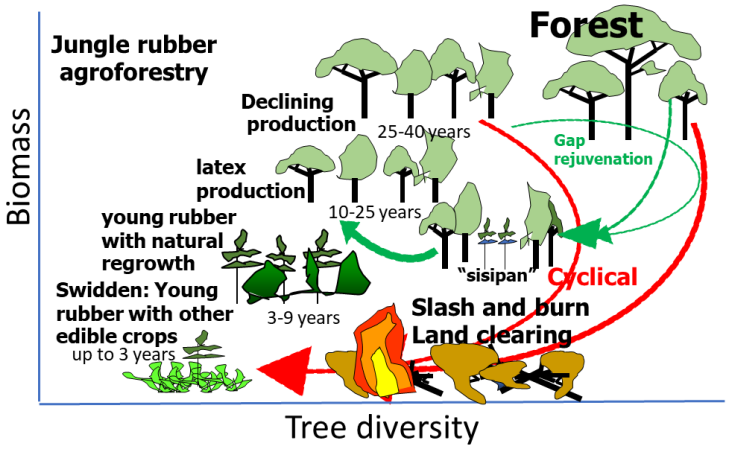
2.1.26 Minimizing the 'footprint'

… (negative environmental consequences per unit product) may lead to intermediate levels of intensification, depending on context, as shown for palm oil and emission-saving feasible in relation to N-fertilizer use.[43]



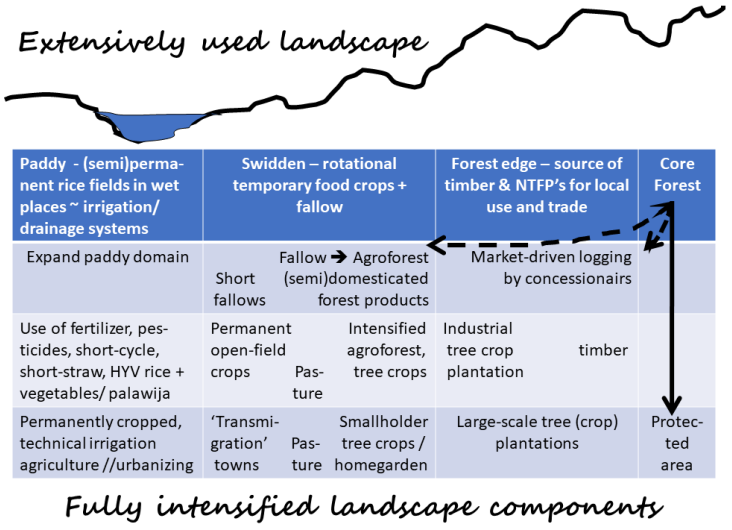
2.1.27 Cyclical vs internal rejuvenation ('sisipan')

agroforests reflect two types of forest management: gap-level (underplanting) or whole-field (even-aged); if burning is not allowed, food crops are skipped.[44,45]



2.1.28 Landscape-scale intensification

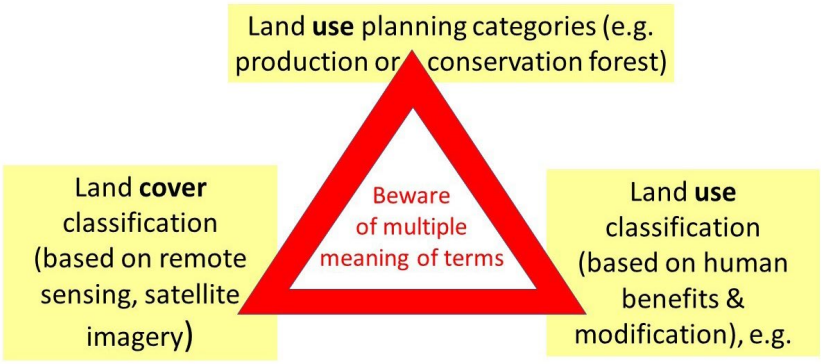
At a landscape scale an intensity gradient often exists, with the least intensive land use furthest from the homes or village; intensification operates on this whole gradient rather than on individual land uses.[1]



2.2 Social and policy perspectives on land and landscapes as part of a ToP

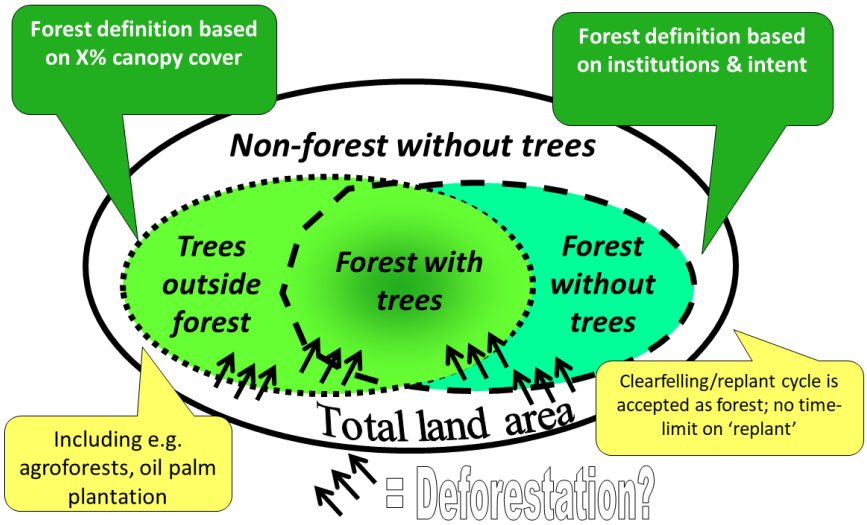
2.2.1 Land cover vs land use vs land use rights

… may all refer to 'forest' but focus on its structure, its function and the benefit allocation, respectively. 'Forest' may mean different things. Legends of land cover and land use maps need to be reconciled with local knowledge and terminology.[46]



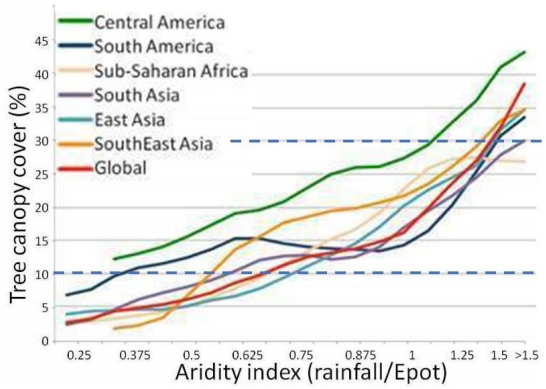
2.2.2 Forests vs Tree cover

Two different angles are on forest as vegetation (or tree cover as metric), and forest as institution imply that 'deforestation' can mean the loss of tree cover and/or the transfer to other institutional domains.[47]



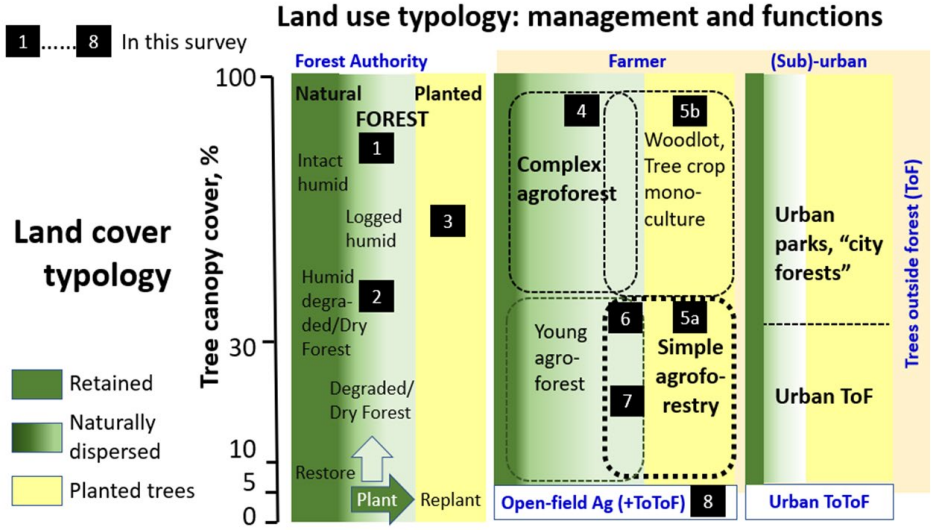
2.2.3 Tree cover in agricultural lands

… is, across all tropical regions, related to the hydroclimate, but it also varies between regions, with relatively high values in Central America that still deserve to be better understood.[48]



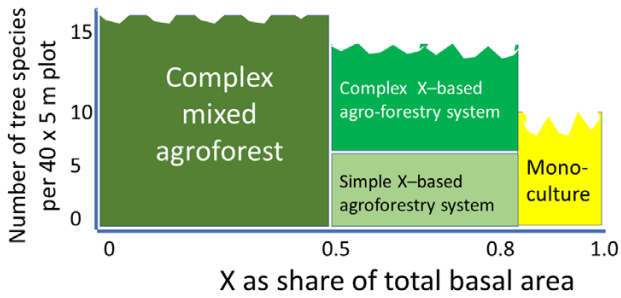
2.2.4 Land cover typology

… intersected with institutional regimes in forest-authority, farmer-managed and (peri) urban landscapes.[33]



2.2.6 Agroforestry categories

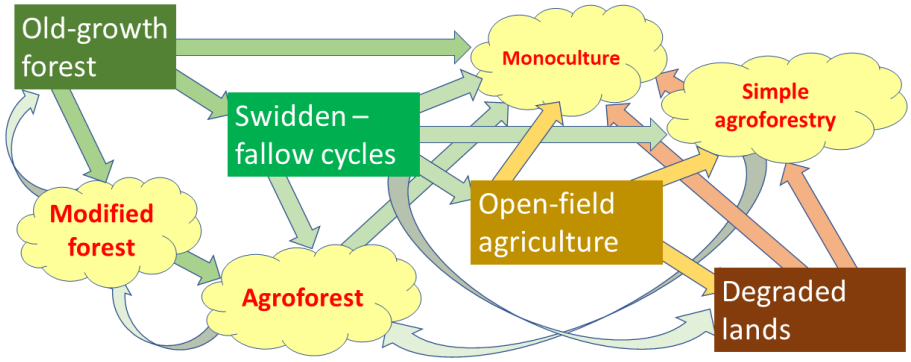
... distinguish 'monoculture', simple and complex agro-forestry systems, and complex, mixed agro-forest (the latter usually are 'multistrata'),based on tree diversity and relative share of the main tree in the total basal area.[30,49]



2.2.7 Evolving tree crop production systems

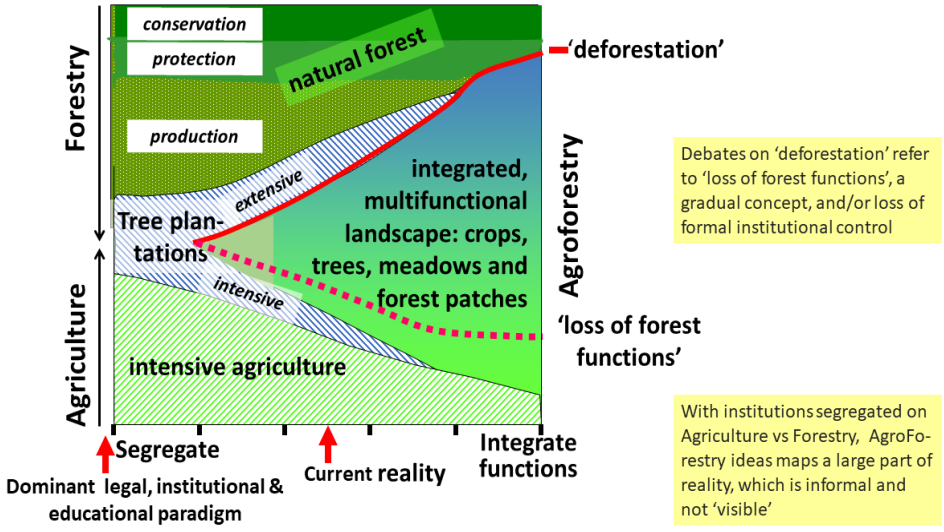
... derive from four types of preceding land uses, providing multiple interpretations of 'deforestation' and 'restoration', but also influencing soil and vegetation.[50]

Four origins for four modes of tree crop cultivation:



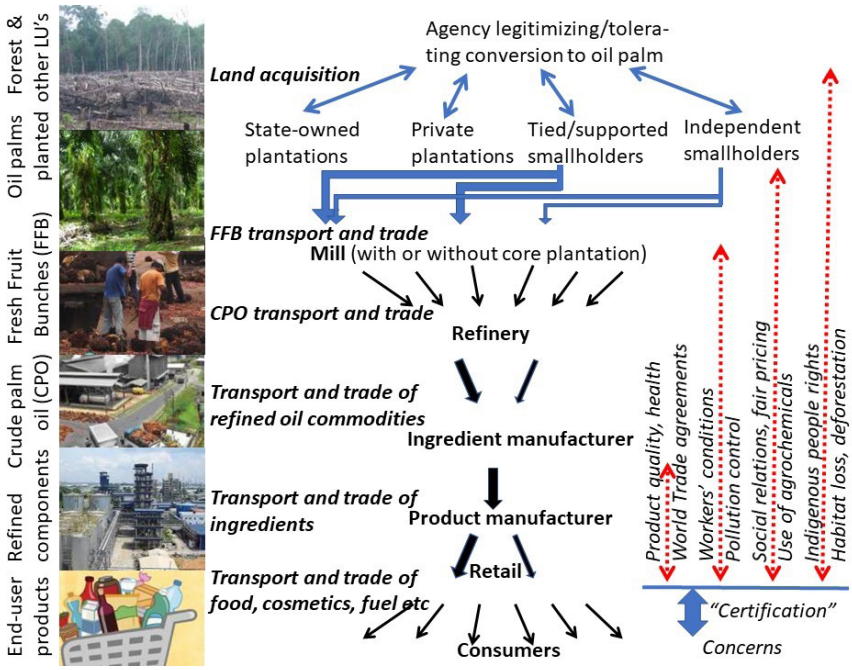
2.2.8 Permitted land uses

Permits typically differ between 'agricultural' and 'forestry' designations of land, with further distinctions between productive (logging and/or plantation oriented), (watershed) protective and conservation-oriented forest uses.[46,51]



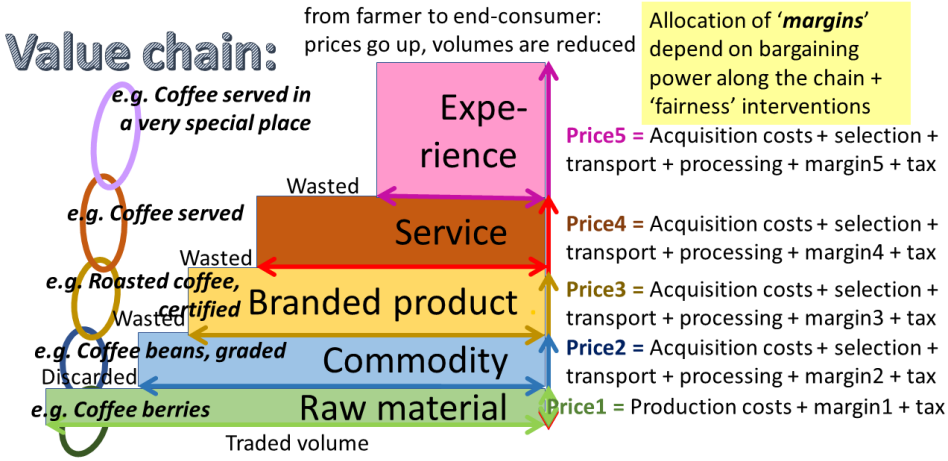
2.2.9 Supply chains

from farmers' hoe to consumers' fork are also part of 'value chains' where the end-user value is increased while the volume is reduced (generating by-products or waste) along the chain, that involves transport, processing, refinement, blending, branding and retail — as shown here for palm oil as example.[52]



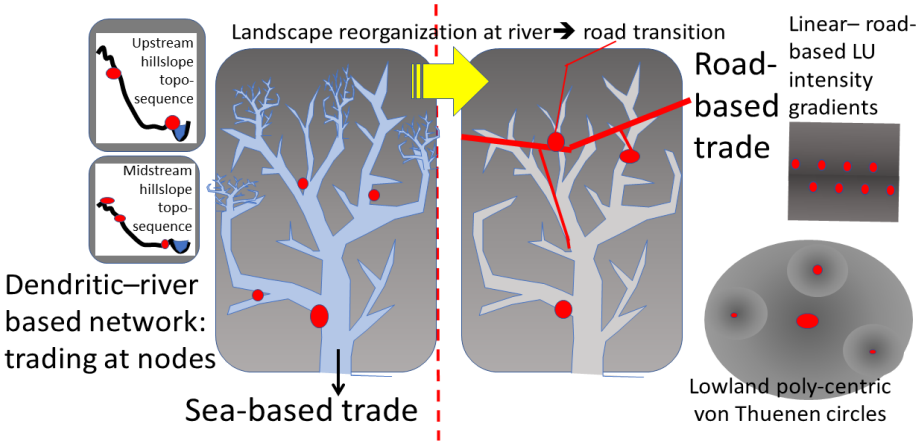
2.2.10 Value chains

Within supply chains value changes and so do prices per unit volume, as analysed under the 'value chain' concept, with coffee as classical example.[53]



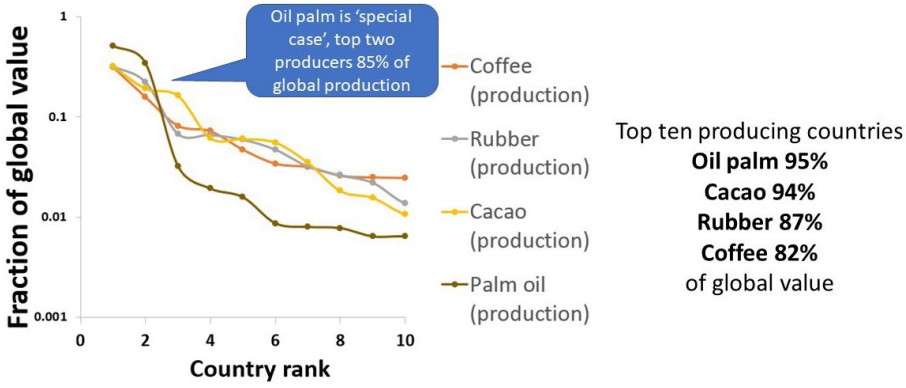
2.2.11 Economic geography

Distance to roads/rivers, market, or processing plants determine profitability of tree crops as part of overall land use and help explain which economic activity develops where, and how transport modes shape landscapes.[54]



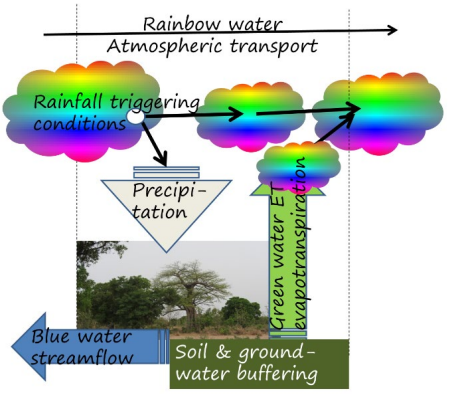
2.2.12 Global trade source dependence

Global trade, seen as a self-regulating system, balances the scale-advantages of specialization at country level, with the risks of all eggs in one basket, resulting in similar rank-contribution relations.[55]



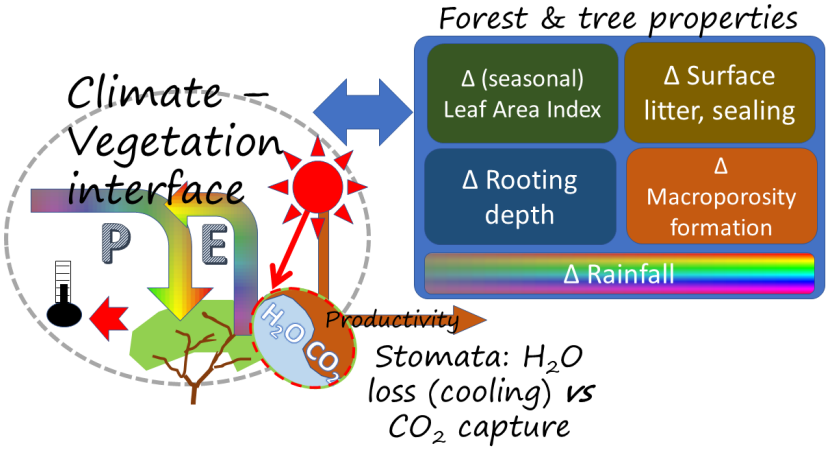
2.2.13 Water conflicts

... may be older than land conflicts in many environments. Rules start with 'blue water', but expand to other 'colours'. Beyond 'green' water stored in soil and used by vegetation and 'blue' water in rivers and lakes that can be used for irrigation, domestic and industrial processes, 'brown' water refers to pollution control of recycling and atmospheric moisture 'rainbow' water is affected by land use change.[56]



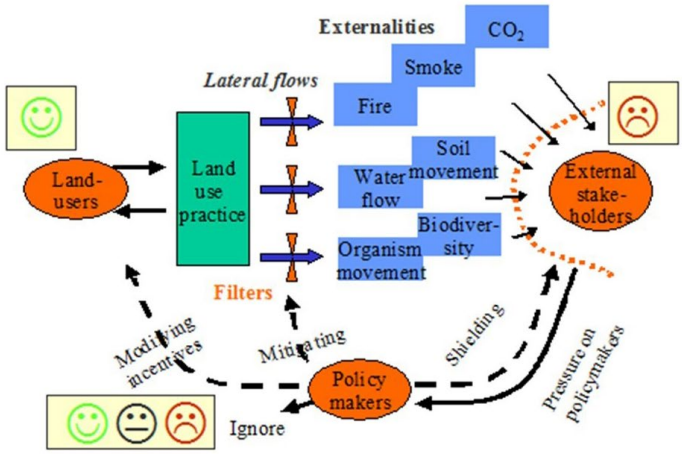
2.2.14 Taxing tree plantations for their green water use

... as South Africa pioneered. Fast-growing, often exotic trees, grow faster, keep their stomata open during a longer part of the year and as such may reduce blue water yields in streams and rivers, but have stronger effects on cooling and downwind rain.[19]



2.2.15 Buffer and filters

Attribution of 'lateral flows' (e.g. water, soil, organisms, fire) perceived by external stakeholders to effects of land use, can be complex where flows are modified by 'buffers' and 'filters' in the landscape, that depend on location and property rights.[57]



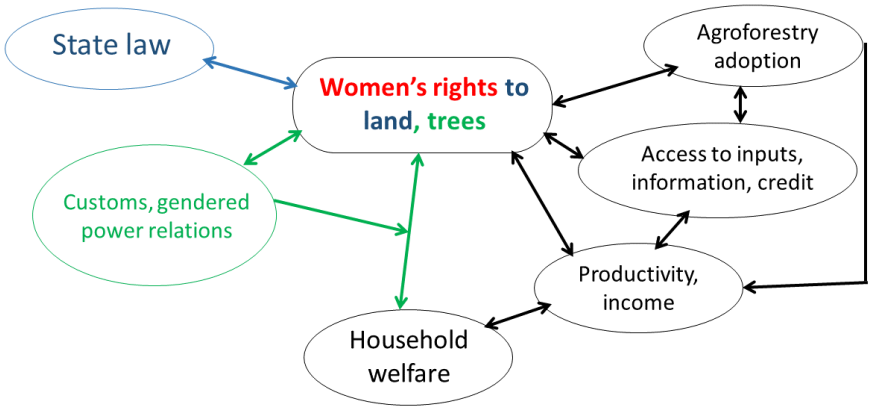
2.3 Social stratification as part of Theories of Place

2.3.1 Bundles of rights

… that defines 'tenure', expanding on the five aspects in the seminal study by Eleanor Ostrom and colleagues.[58]

2.3.2 Stratified property rights

... by gender or social class (e.g. 'caste') have been and still are a major obstacle to sustainable development.[59]



2.3.3 Indigenous people self-identifying as historical right owners

… are internationally supported in claims regarding national governments.[60,61]

The General Assembly,

Guided by the purposes and principles of the Charter of the United Nations, and good faith in the fulfilment of the obligations assumed by States in accordance with the Chapter,

Affirming that indigenous peoples are equal to all other peoples, while recognizing the right of all peoples to be different, to consider themselves different, and to be respected as such,

...

Affirming further all doctrines, policies and practices based on or advocating superiority of peoples or individuals on the basis of national origin or racial, religious, ethnic and cultural differences are racist, scientifically false, legally invalid, morally comdemnable and socially unjust,

...

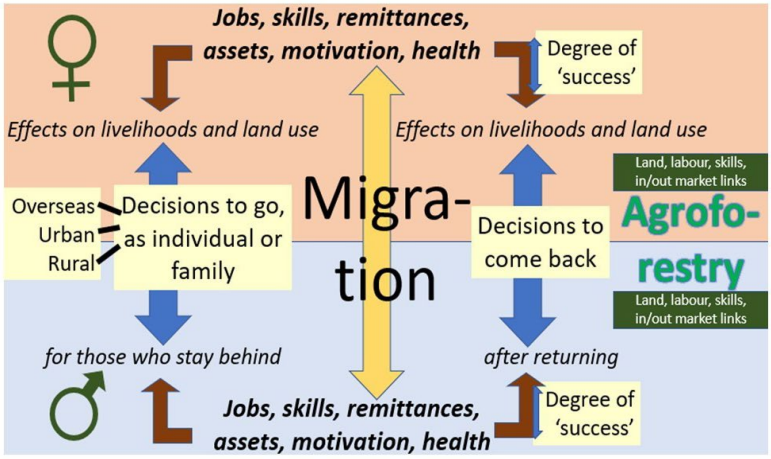
Concerning that indigenous peoples have suffered from historic injustices as a result of, inter alia, their colonization and dispossession of their lands, territories and resources, thus preventing them from exercising, in particular, their right to development in accordance with their own needs and interests,

...

Solemly proclaims the following United Nations Declaration on the Rights of Indigenous Peoples

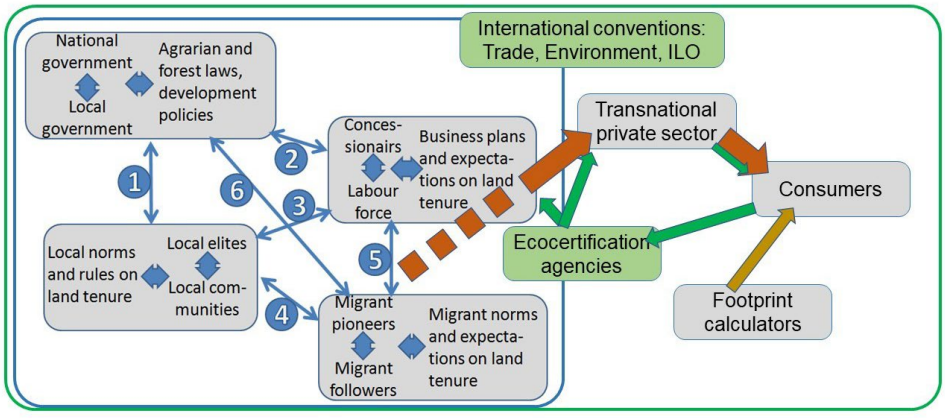
2.3.4 Migration decisions

… influence demography, especially from high to low population densities. Decisions depend on age and gender. Permanent or cyclical is only clear in hindsight. Migration history influences tree crop spread and agroforestry adoption.[62]



2.3.5 Migrants as stakeholders

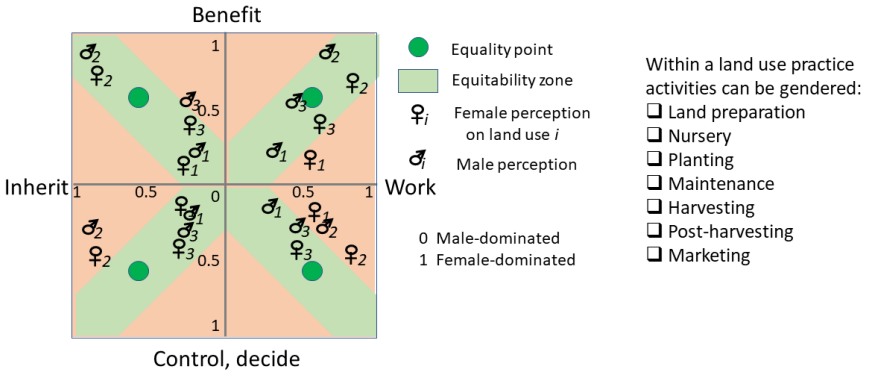
... linked to tree crop production landscapes and their markets are easily overlooked where migrants interact with local elites on land acquisition and with large-scale plantations as labour force.[63] When right-holders are distinguished as subset of stakeholders, migrants are differentiated from those born into local communities, depending on how they were assimilated into local institutions.



2.3.6 Gender analysis

… of land use practices needs to consider the way work (effort), benefit (net of costs), inheritance rules and control (decision-making) are distributed over male and female house-hold members, according to male and female infor¬mants. Specific inheritance rules can apply to land, trees, livestock.[64]

Gender roles in land use and value chains (GRoLUV)



2.3.7 Gender perspectives in selecting tree species

… can contribute to overall diversity as the example for Southeast Sulawesi Indonesia) shows; female and male farmers rank trees differently.[30,65]

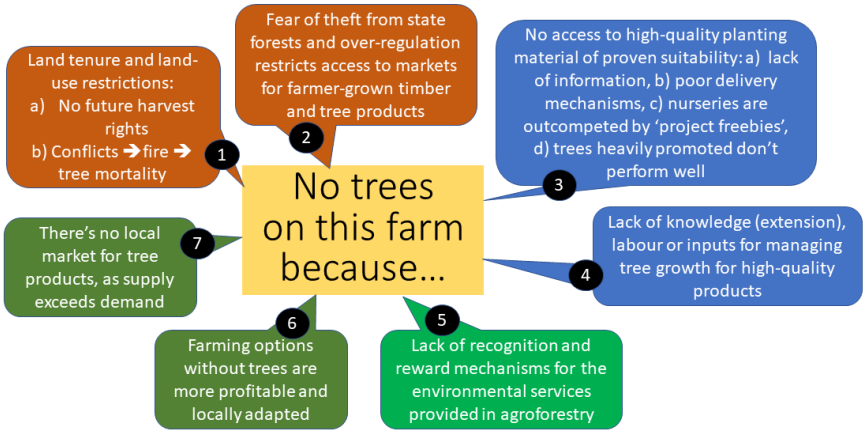
Species; Main Benefits	% of plots	Female	Male
Theobroma cacao (cacao); Bean	100	1	1
Pogostemon cablin (patchouli); Oil	78	2	2
Gliricidia sepium (mother of cacao); Fodder (leaves), support tree for pepper	78	9	11
Musa sp (banana); Fruits, vegetable (flower), cultural services (leaf), toys (trunk)	67	4	-
Cocos nucifera (coconut); Fruits, cultural services (leaf), roof (leaf), toys (trunk)	56	5	-
Capsicum annum (chili pepper); Vegetable/spice	56	7	-
Piper nigrum (pepper); Vegetable/spice	44	6	10
Fagraea fragrans (tembesu); Timber	44	10	3
Tectona grandis (teak); Timber	44	11	4
Anthocephalus cadamba (jabon); Timber	44	-	5
Durio zibethinus (durian); Fruits	44	3	6
Lansium domesticum (langsat); Fruits	22	-	7
Mangifera indica (mango); Fruits	22	-	8
Nephelium lappaceum (rambutan); Fruits	22	-	9

2.3.8 Youth and intergenerational issues.

Globally, very few farmers hope their children to be farmers — even when they prefer to pass on their farm to a next generation, rather than sell out. The life-cycle of farmers matters for understanding decisions regarding trees, that may live as long, or longer than people. Trees, e.g. valued timber sources. can act as savings for retirement or emergency expenses. Decisions to clear and replant may require resources that only older people have, and the workforce of younger ones. Such resources may be combined when new families form and work on land owned by in-laws/ parents, while establishing new farms. Assumptions of an open market for land labour may miss these patterns. Child labour in its exploitative forms, preventing children opportunities for schooling and leisure, is part of rural poverty and more easily condemned than avoided. Learning in practice is important, but distinct from exploitative forms of child labour.[66] Promoting the virtues of agricultural entrepreneurship to urban youths has been tried in many cultures. (Image from 'Propaganda Bistro', Hanoi, Viet Nam).

2.3.9 WhyNoTree analysis of local constraints to tree presence

On-farm tree presence and/or diversity varies with context. There are some valid reasons (#6, #7) for lack of interest by specific farmers in trees, but many reasons, if emerging as important in a local context, can lead to remedial actions.[67]



2.3.10 Land use profitability analysis

… uses the toolbox of agricultural economics to convert technical descriptions of inputs and outputs over the life-cycle of a production system into (discounted) cash flow.[68]

Land use profitability analysis (LUPA)

Analysis of a land use practice

Year	Stage	Costs (C)	Benefits (B)
0	Land acquisition, clearing	Labour, inputs, tools	Harvest: volume * price
1	Planting, weeding	*idem*	*idem*
2	Maintenance	*idem*	*idem*
3	…		
…	Harvesting	*idem*	*idem*
…	Harvesting	*idem*	*idem*
n	Final harvest	*idem*	*idem*

Net Present Value (NPV):

$$NPV = \sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

Where I is the discount rate

Returns to labour (R2L):
wage rate at which NPV=0

Years to positive cash-flow
first year with NPV sum >0

2.3.11 Labour accounting

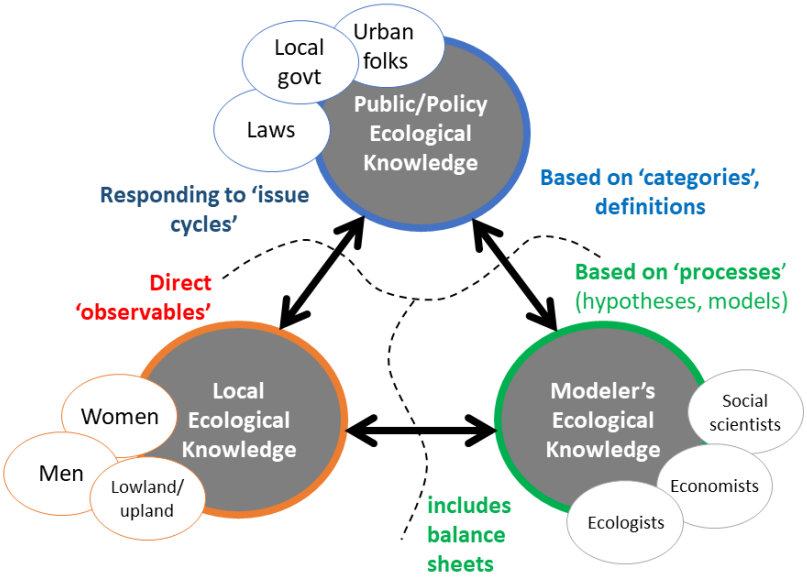
In urban, industrial employment it may be clear what one day of work means, and what a wage rate implies in terms of hours of work, throughout a year. In agriculture, there are seasonal peaks (e.g. harvesting periods) and troughs. Sometimes, family labour is called in during peaks. Tasks such as tapping rubber are best done during early hours of the day, allowing it to be combined with other tasks during the rest of the day — if these exist locally, on-farm or off-farm. How are the 3 – 4 hours per day accounted for in economic analysis? On rainy days trees can't be tapped – are the days not worked included in the analysis? Labour accounting is not as easy and straightforward as it appears to be; synergy with other farm components is easily misrepresented.[69]

2.3.12 Land quality change.

Land rents, payable yearly, and possible change in asset value of land (especially important in areas of peri-urban expansion) are not normally included in analysis of land use profitability — because they may be independent of specific land uses to be compared. Thus, is not always justified. For example, in Vietnam the compensation paid by governments as part of urban expansion to farmers is higher for orchards than for open-field agriculture: this was quoted as a main reason for farmers to plant trees in these contexts. In the Philippines, increase in land value after terraces formed on steeply sloping land was found to exceed any cost-benefit estimate of the land use, with or without trees.[70]

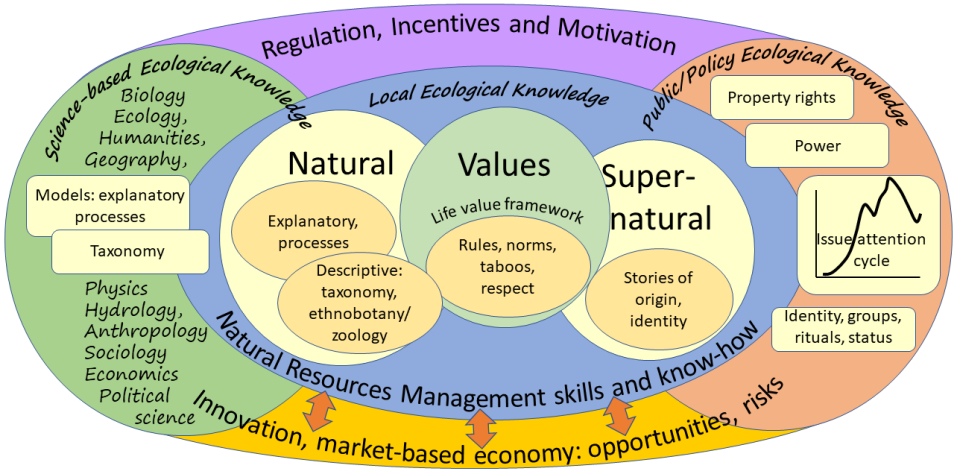
2.3.13 The diversity of Local ecological knowledge

… has triggered much of science-based exploration, but constructed a different explanatory basis; it also interacts with public/policy knowledge that tends to focus on categories and definitions, demarcating rights.[71]



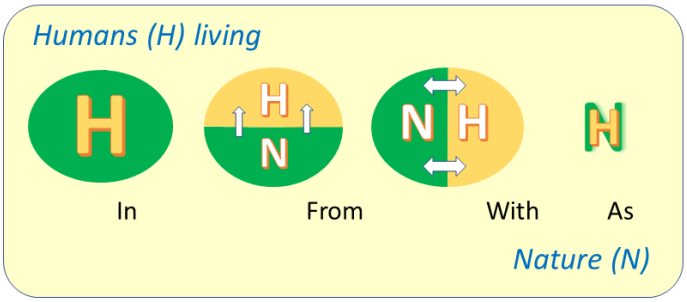
2.3.14 The scope of local ecological knowledge

… is often associated with ethno-botany/-zoology, but also has an important 'explanatory' logic to offer, interacting with science and policy spheres; it is important to check how 'local' local is, especially where intellectual property rights are claimed and neighbours can be negatively affected.[72,73]



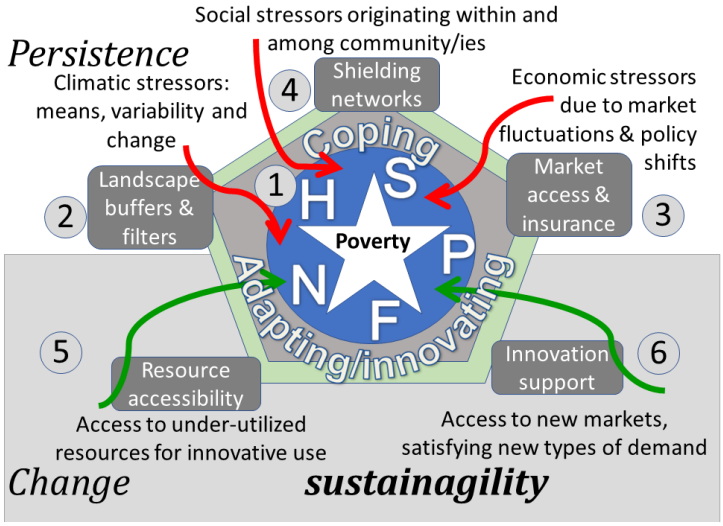
2.3.15 Human relationship with Nature

… have been analysed under four headings.[74]



2.3.16 Human vulnerability

... as dynamic equivalent of 'poverty' can be due to low levels of any of the five 'capitals' (H = Human, S = Social, N = Natural, F = Financial, P = Physical (infrastructure). In the face of negative stressors the capitals can help to buffer and shield people, in the face of opportunities for positive change, they can facilitate innovation and adaptative change, also known as 'sustainagility'.[75]



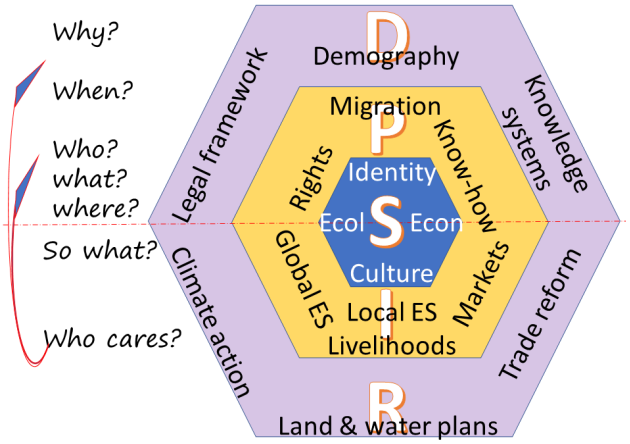
3

The So what?, Who cares?, and Why? of a theory of change (ToC)

Processes, feedbacks and functioning of social-ecological systems shape a Theory of Change.

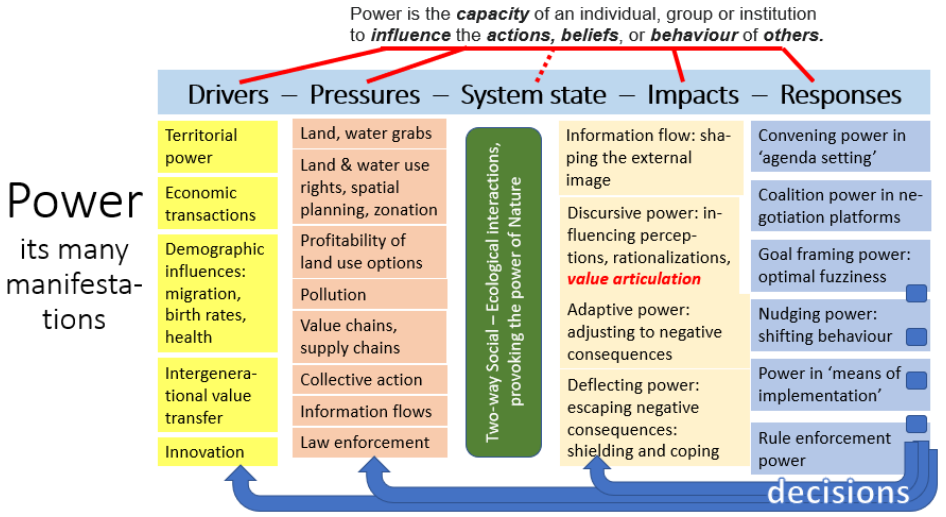
3.1 Theories of Change (ToC)

… can build on the analysis of Drivers, Pressures, System state, Impacts and Respon¬ses (DPSIR) with nested scales for households, communities/landscapes and national/global levels of decision making.[76]



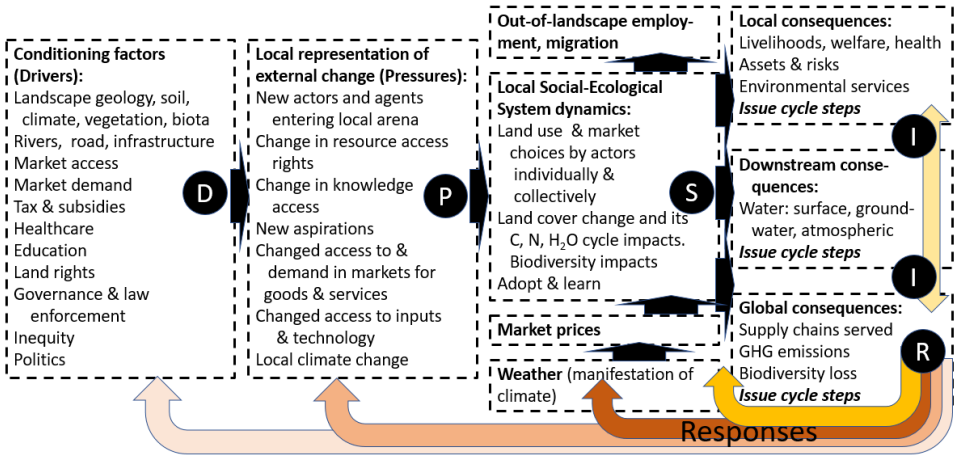
3.2 Power differences

… along a DPSIR chain, are the focus of a political ecology/ economy analysis of land use change.[77,78]



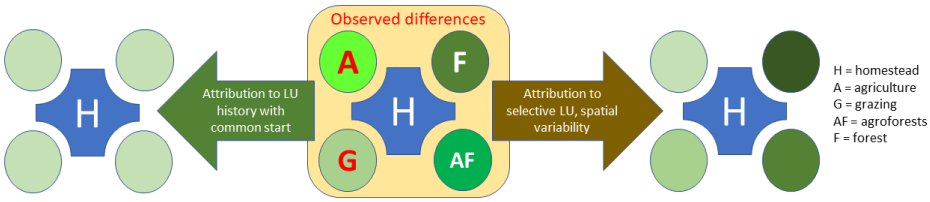
3.3 Land Use drivers as explanatory factors

… for participatory assessment of land use change and its drivers.[78]



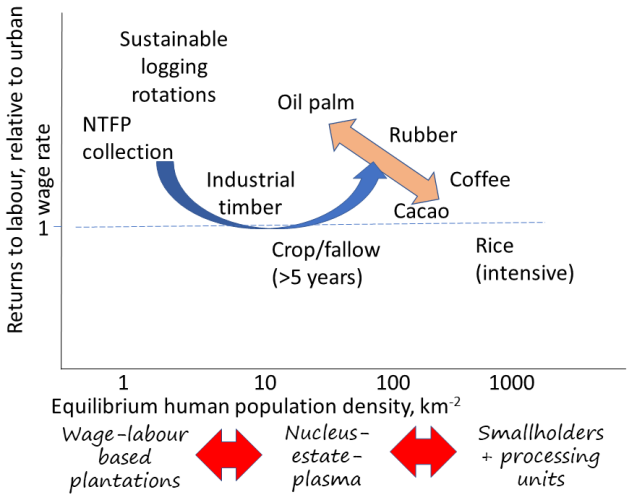
3.4 Chronosequence pitfalls

As effects of land use change on 'slow variable' such as several important soil properties take time, it is common practice to 'substitute space for time' in a so-called 'chronosequence' interpretation of land use practices of different age but a supposedly similar starting point and transition trajectory. The problem is that the underlying assumptions are hard to verify. Against such interpretation is the understanding that land use and land use change are not 'random'. Farmers have throughout history been pretty good at selecting the best soils and landscape positions within the range of options available, and the time of conversion may not be random with respect to the changes that occurred. Reconstructing such change can help identify the social dimensions of ecological change. Another help is the use of 'conservative co-variates', unlikely to be affected by land use change, but useful as markers of soil quality. Soil texture (sand, silt, clay fractions) is commonly used as such, although it change rapidly under extreme conditions (e.g. clay becoming bricks during fire events). If pedotransfer functions, such as C_{ref} are available, changes in C_{org}/C_{ref} may provide more sensitive indicators of soil change. For example, initial results of higher Corg in rubber agroforests than remaining forests in the same landscape, were related to differences in clay content, disappeared with C_{org}/C_{ref} as metric.[79]



3.5 Economic demo/geography

Land use choices interact with urban wage rates as next generations vote with their feet along the rural-urban continuum; land use systems can be characterized by the equilibrium human population density for whom they provide (self) employment, and the returns to labour that they provide.[80]



3.6 Institutions

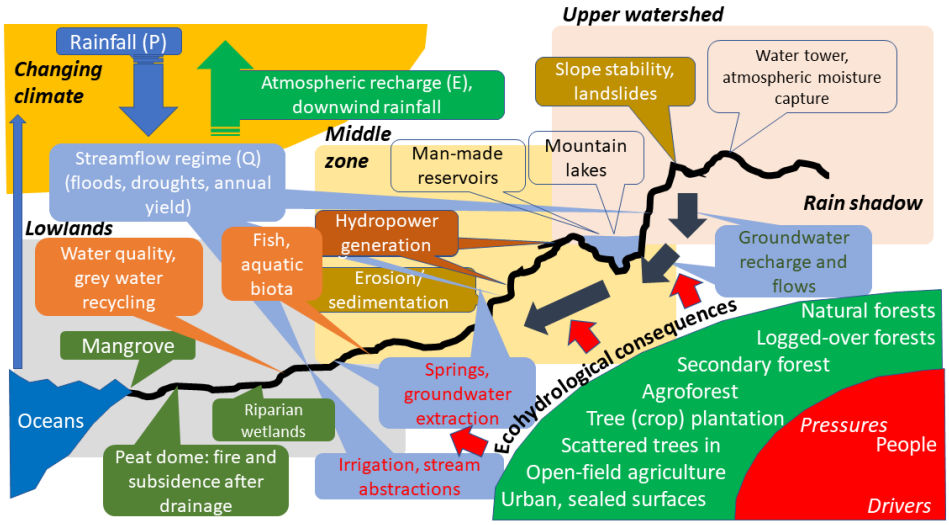
… and collective action modify rights, define responsibilities, impose sanctions, and modify social motivation for individual choices.[81]

Humans can achieve further 'coordination' by imposing or agreeing on 'rules of the game', also known as 'institutions' that restrict individual freedom (selfishness) and force alignment to 'collective action'. Human sociality is based on Groups, Rituals, Affiliation, Status, and Power, in a cultural context. Institutions depend on shared values, goals, membership rules and accountability.

Flocks of birds may move in coordinated ways, without any 'leadership', 'goals' or 'management'. Group-level behaviour can emerge from simple rules that every bird tries to avoid crashing into neighbours, adjusting speed and direction to the ones in front, left and right.

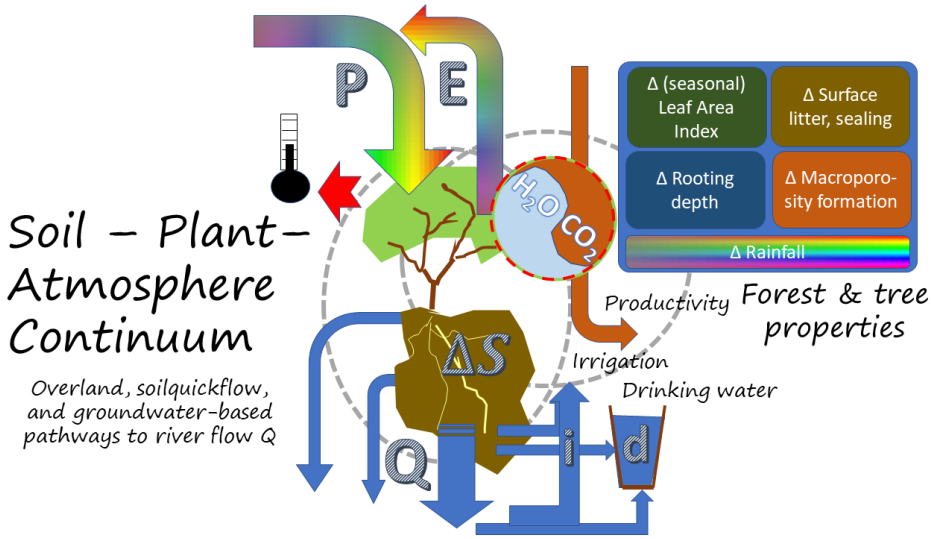
3.7 Hydrological impacts

… of land use change, including decreases and increases in tree cover, depend strongly on the position in the land¬scape where the changes occur.[82]



3.8 Water management

… has to balance the downstream interests in agricultural, domestic and industrial water use with the quantity/quality trade-offs that derive from upstream land use.[83]



3.9 Local monitoring, citizen science

Bridging the gap between local (specific) and science-based (generic) observation methods has allowed empowerment of local stakeholders in public discussions on environmental issues.[84,85]

Village-level monitoring of biological water quality

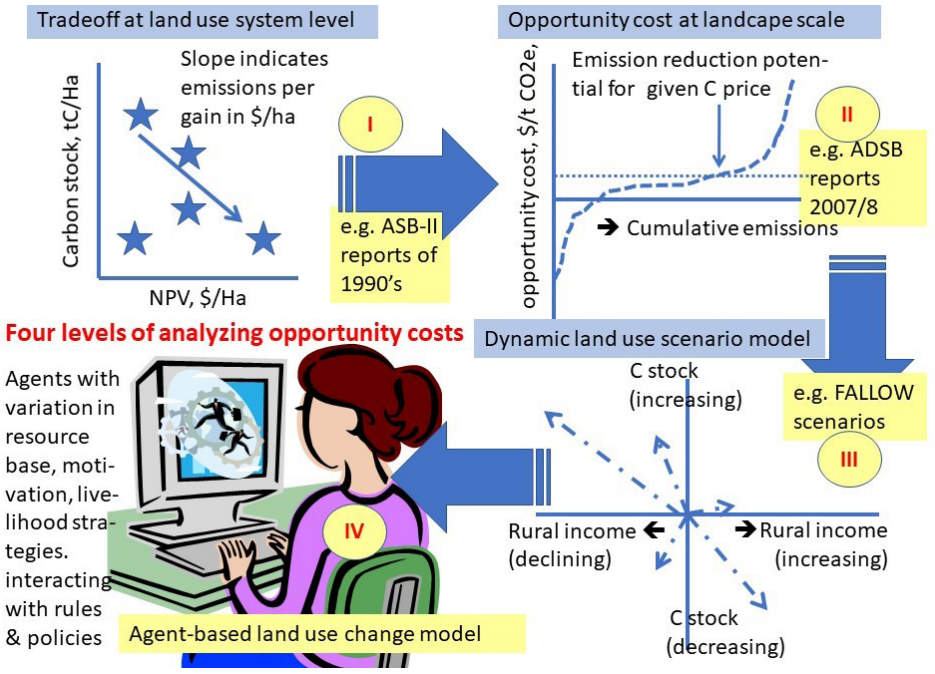
Mae Chaem - Thailand

Biological indicators of clean water

Lampung - Indonesia

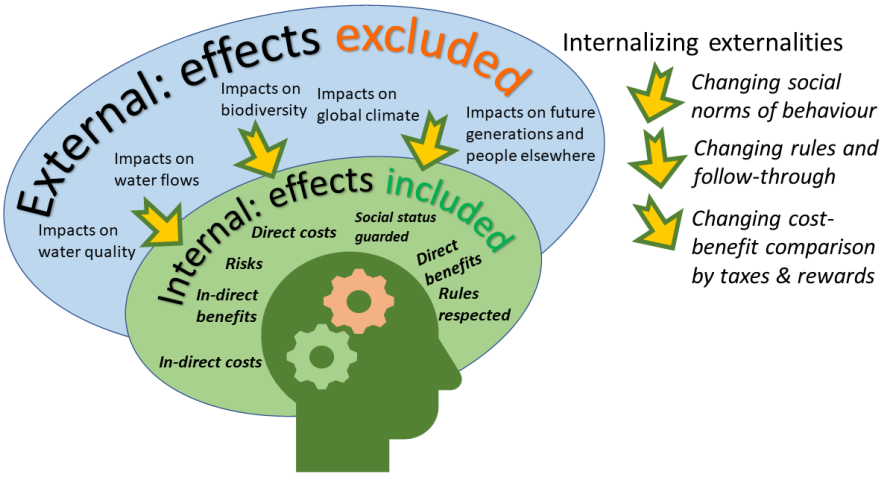
3.10 Tradeoff analysis in 4 steps

Tradeoffs between environmental and economic performance can be analyzed at system level (comparing time-averaged properties across land use options), in spatially differentiated 'opportunity cost' formats, in lumped dynamic land use change models and in agent-based decision models.[86,87]



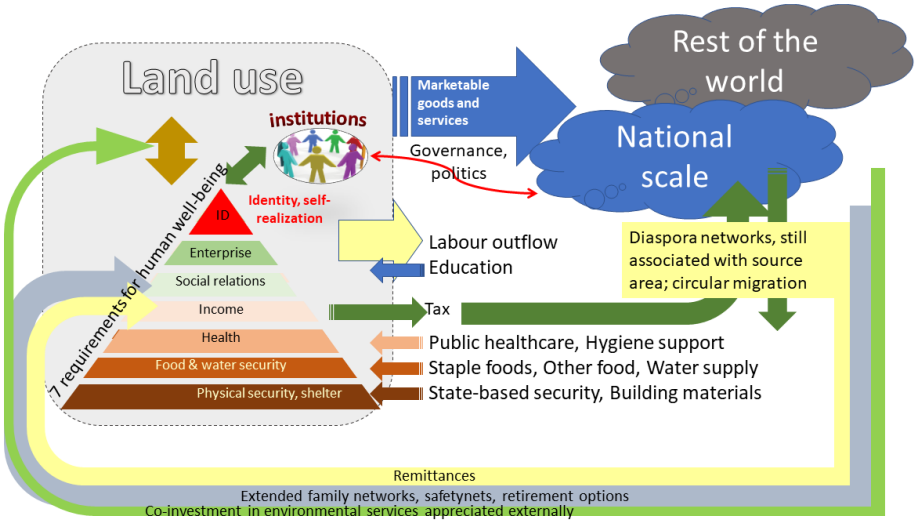
3.11 Internalizing externalities

Human brains are wired to make decisions, not to ponder about all possible side-effects on every other part of the world — but sometimes such effects, ignored as 'externalities' can come back to haunt us. Attempts to 'internalize' such externalities have to guard against making decisions too complex — but in their simplification they shift the borders of externalities, not eliminate them.[88]



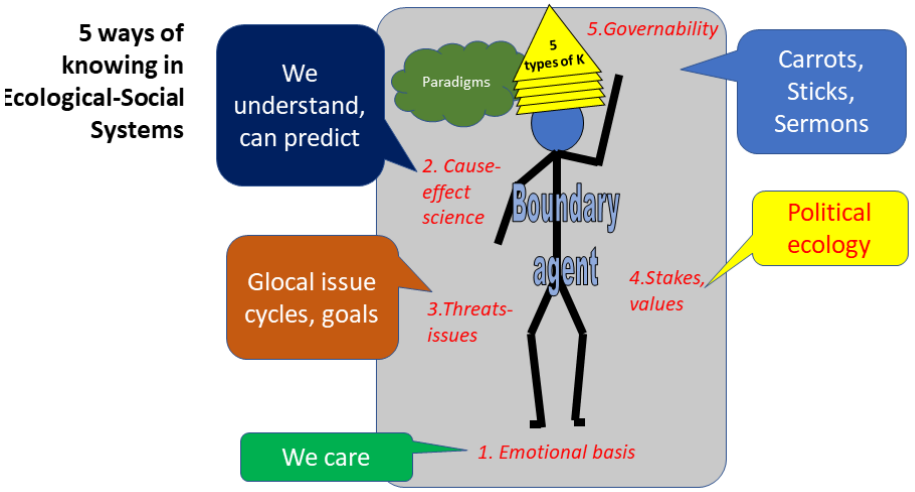
3.12 The Maslow pyramid

... of human well-being identifies seven require¬ments: seeking security in basic needs before self-realisation, as part of the human relations with a landscape and the external world.[6]



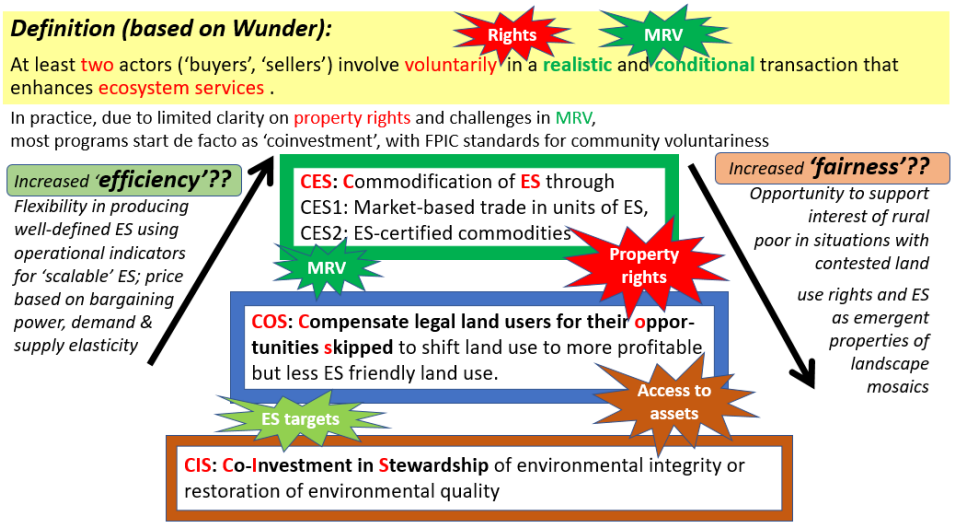
3.13 Five ways of knowing that jointly can change social-ecological systems

Returning to 1.1 we can now better appreciate the complementarity of the five ways of knowing that a boundary agent needs to reconcile.[89]



3.14 Three paradigms within the 'payments for ecosystem services' (PES) umbrella

… are Commodification (CES), Compensation (COS), Coinvestment (CIS).[90,91]

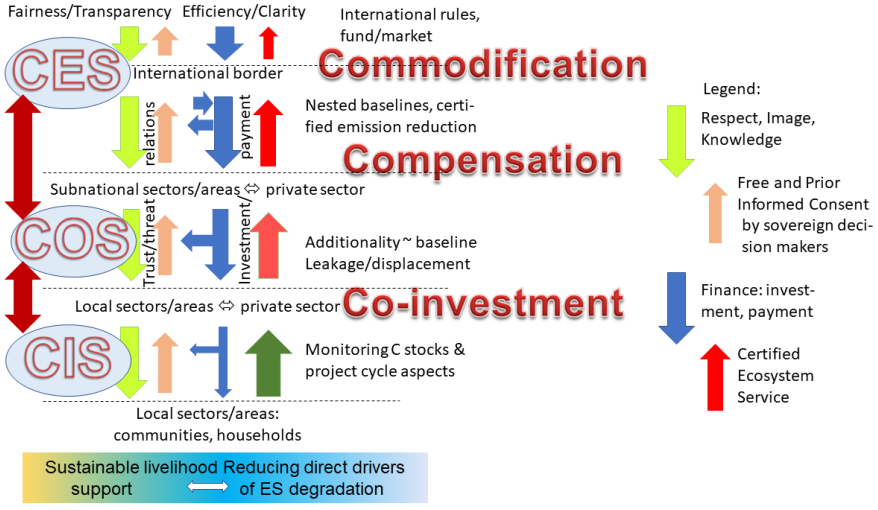


3.15 Biodiversity paradox

Urban consumers have more and more choice of foods, derived from farms and landscapes that get less and less diverse. Compare markets in Luang Prabhang (Laos) and Wageningen (the Netherlands) on Mekong and Rhine river bank, respectively.[92].

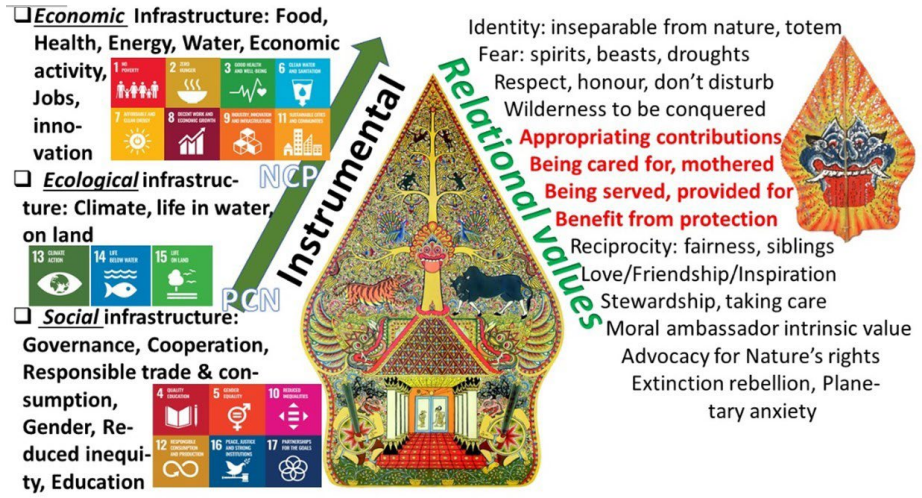
3.16 Combining PES paradigms across scales

… is certainly possible, for example using international borders of countries and subnational jurisdictional entities (geographical or sectoral in nature) as points for exchange, recognizing that a fairness versus efficiency balance needs to be observed in their specific connotation at any scale.[93]



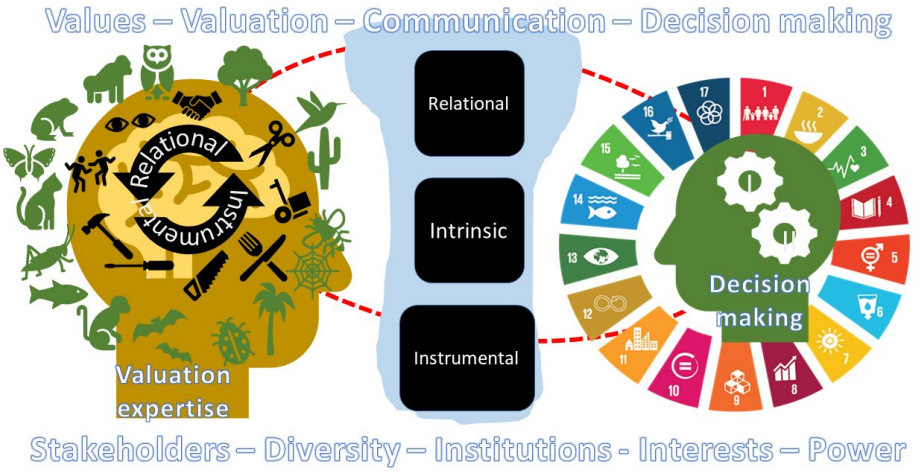
3.17 Instrumental (goal-oriented) and relational values

... influence human decisions at farm, landscape, national and global scales; currently progress is made on deeper understanding of the way relational values complement instrumental 'ecosystem services'.[78]



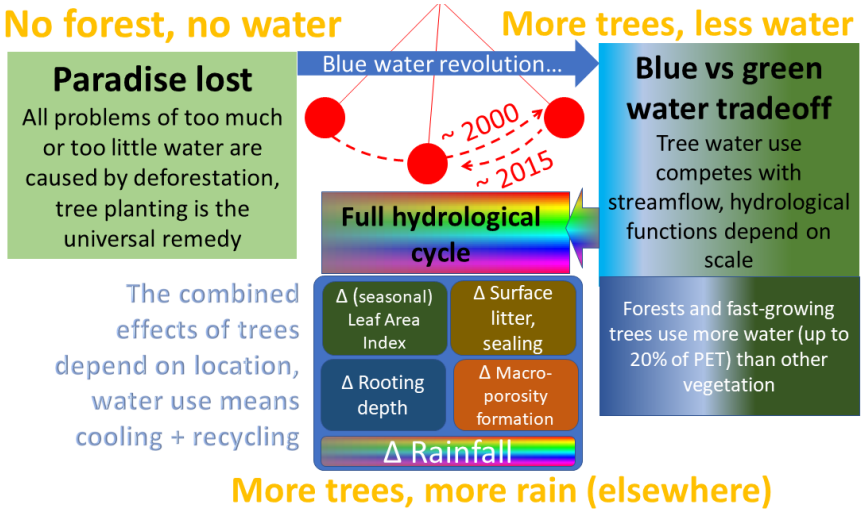
3.18 Valuation as a means of communication

… between 'values held' in the wider community and the multiple concerns a decision maker tries to reconcile. Relational and instrumental (services, contributions) value articulations appeal to different styles of decision making.[94]



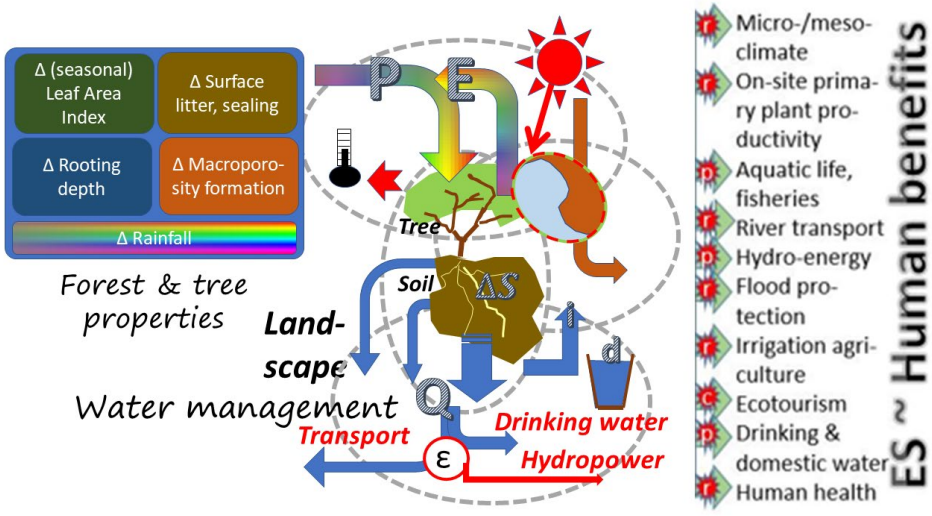
3.19 Three forest-water paradigms shape policy responses

… as simplified guidance suggests that either tree planting is a universal solution, a risk for downstream water users, or an activity that needs to be understood in its local context with scale-dependent answers.[95]



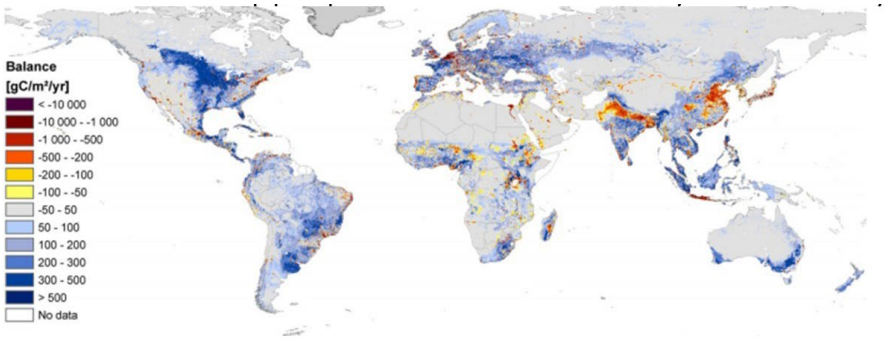
3.20 Ecosystem Services typologies

relate 'ecosystem function' to various types of human benefits (provisioning (p), regulating (r), cultural (c), supporting (s)).[96]



3.21 HANPP: human appropriation of net primary productivity

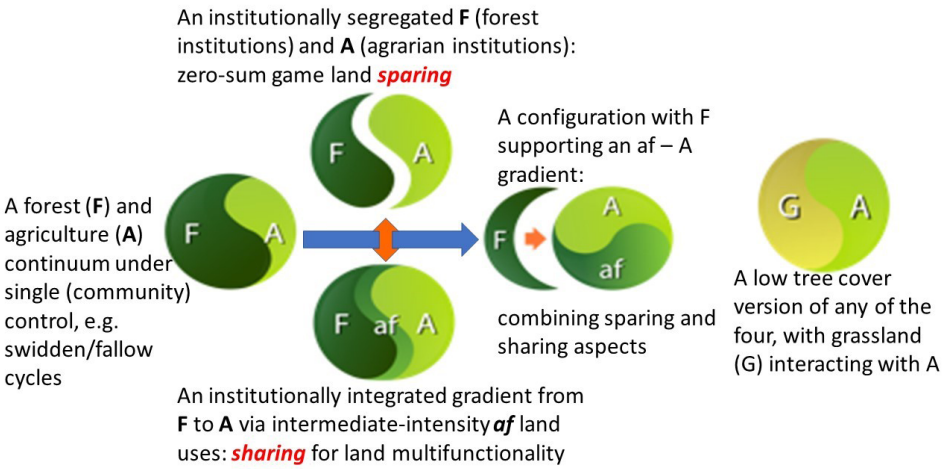
… is a measure of the overall human impact on ecosystems.[97]



Erb, K.H., Krausmann, F., Lucht, W. and Haberl, H., 2009. Embodied HANPP: Mapping the spatial disconnect between global biomass production and consumption. *Ecological Economics*, *69*(2), pp.328-334.

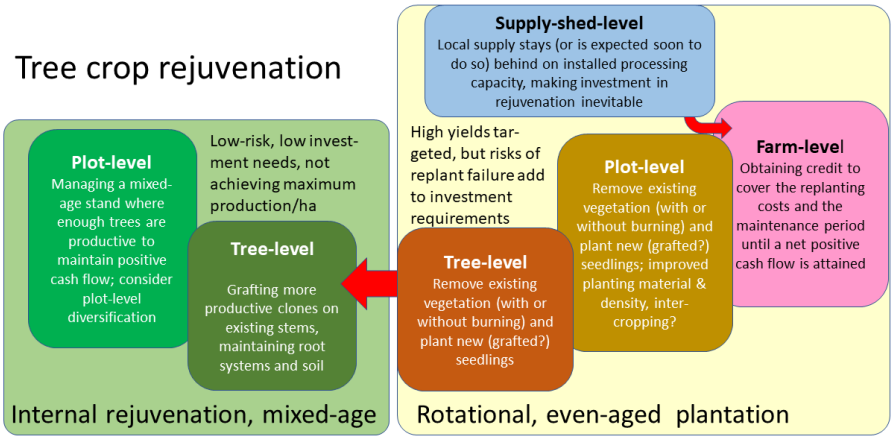
3.22 The land sparing/sharing debate

… has focussed on either closing mono-cultural yield gaps (through conventional 'intensification' – see 2.1.23) or exploiting land equivalent ratios (through 'ecological intensification' – see 2.1.24) as approach to reconciling production and conservation needs of society.[98,99,100]



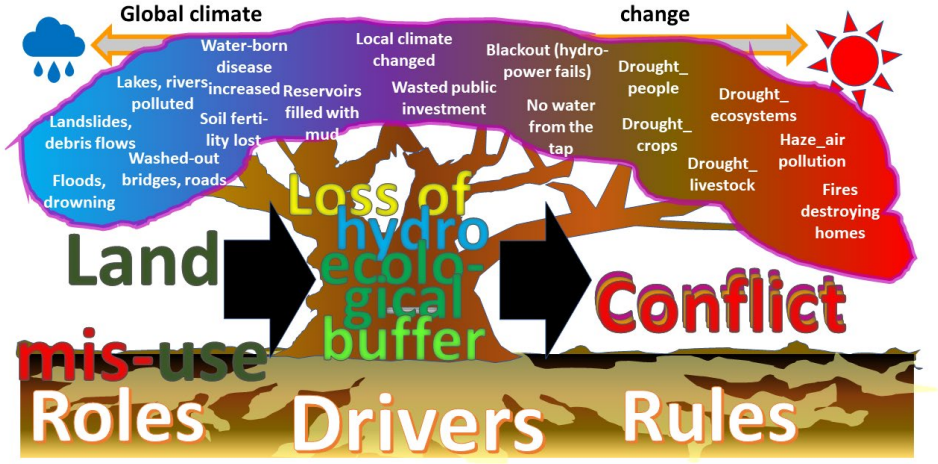
3.23 Pathways for tree crop rejuvenation reach across scales

While large-scale plantations may plan for a rotation with replanting at the end of a cycle, paid for by current production elsewhere, smallholders generally have not been able to save for such and are dependent on external support, often in the form of government programs and subsidized loans. There is, however, an alternative in the mixed-age agroforestry system that are managed at tree, rather than field, level and in which risks are manageable; top-working and in situ grafting can be applied to coffee and various other fruit trees.[101]



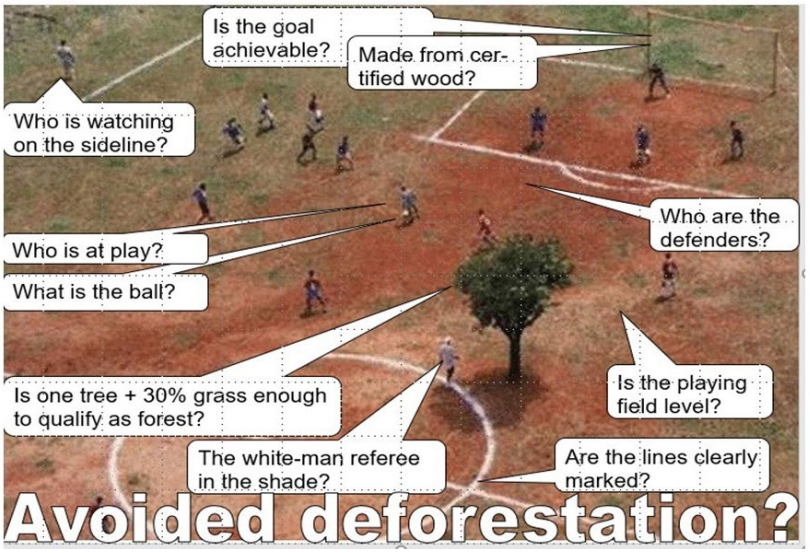
3.24 Addressing root causes, the common stem and the diversified canopy

Metaphorically, trees can be used to describe and analyse issues the way they appear and in their underlying and 'root' causes. Where multiple issues derive from similar structural aspects and root causes, it may be feasible to find coalitions that can address them jointly, rather than one by one.[78]



3.25 Policy questions in reducing deforestation

Since the 13th Conference of Parties of the UN framework convention on combatting climate change, held in Bali in 2007 supported experiments with incentives for 'avoided deforestation', under the heading Reducing Emissions from (forest) Degradation and Deforestation (REDD+), the commonly used metric for deforestation (X football fields per hour) was the basis for exploring many of the institutional issues in a world that wants to play football while maintaining trees.[102]

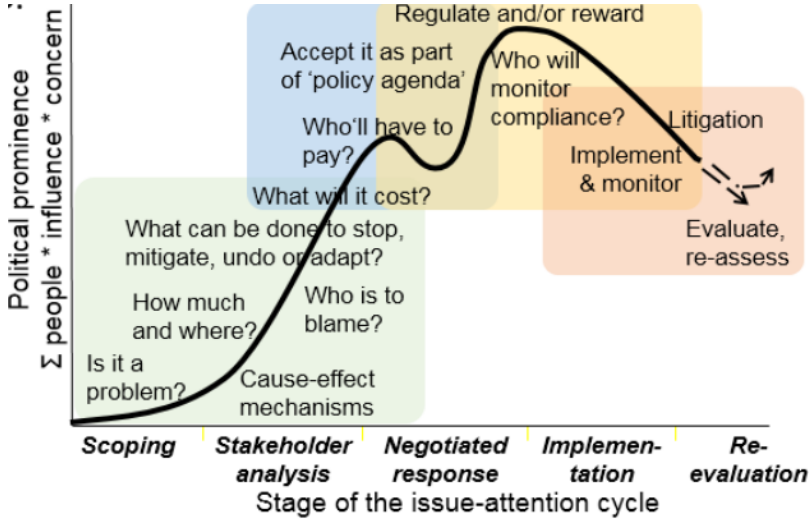


4

Leverage points for a Theory of Induced Change

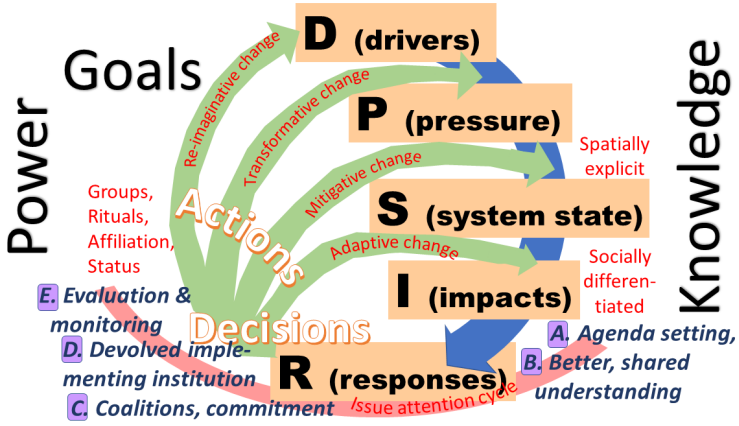
4.1 The issue attention cycle

… describes a common pattern in stages in public discourse and debate that can lead to the emergence of 'new' policy instruments that may (or not) lead to a reduced prominence of the issue in the real-world; progress-markers for stages in the cycle exist.[103]



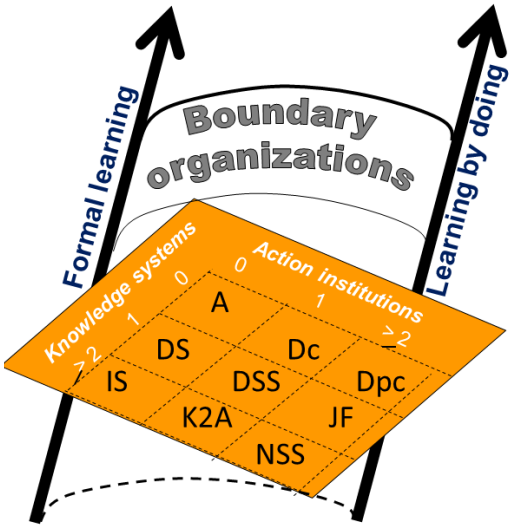
4.2 Leverage points for a Theory of Induced Change (TolC)

… can focus on adaptive, mitigative, transformative and/or re-imaginative change that targets various steps in the DPSIR cycle, interacting with five steps in an issue/decision cycle.[78]



4.3 A combined typology of knowledge and action

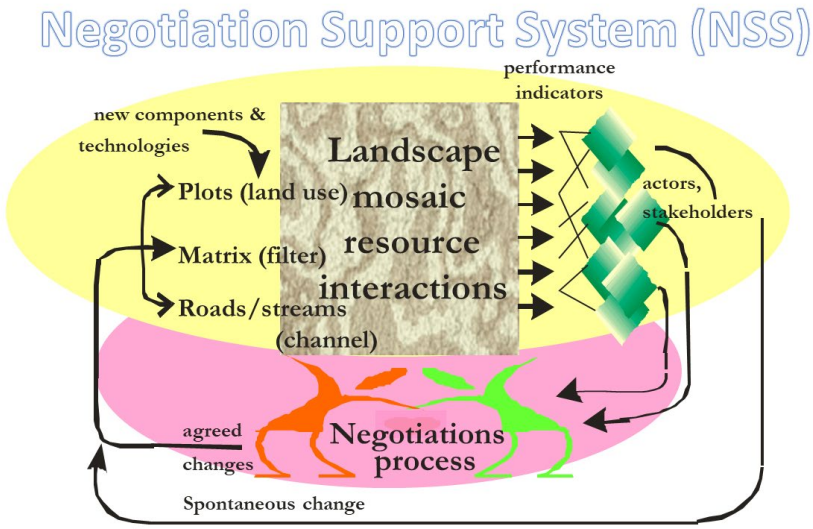
… describes increasing complexity of linking the two.[104]



A = Anarchy
Dc = Centralized governance
Dpc = Polycentric democracy
DS = Disciplinary science
DSS = Decision Support System
IK = Interdisciplinary knowledge
JF = Joint factfinding
K2A = Linking knowledges to action
NSS = Negotiation Support System

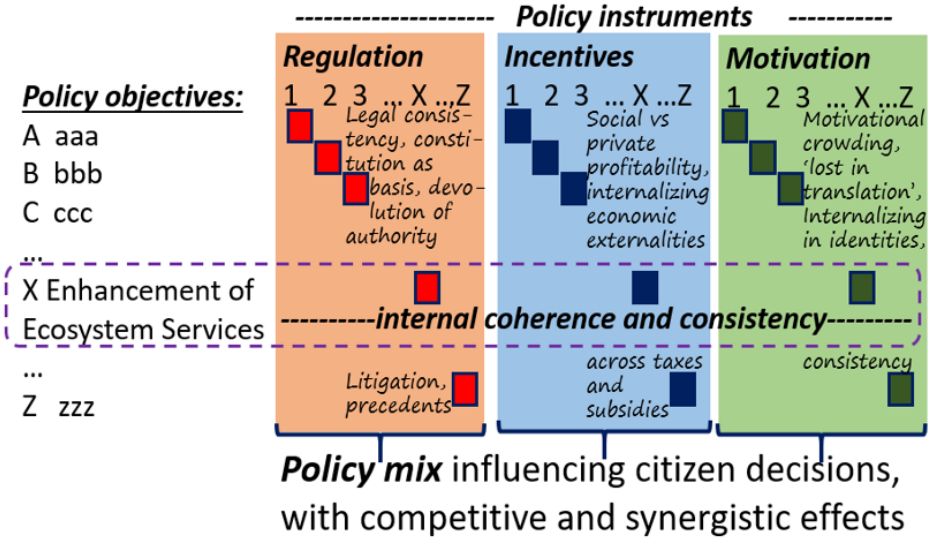
4.4 Negotiation Support Systems (NSS)

The interface of science and policy has often been viewed as one of 'Decision Support Systems' (DSS), where science provides guidance. As alternative the concept of NSS emphasizes that understanding of how current and feasible landscape configuration translate to the performance indicators relevant for multiple stakeholders, interacts with a process-oriented negotiation through multiple feedback loops.[105]



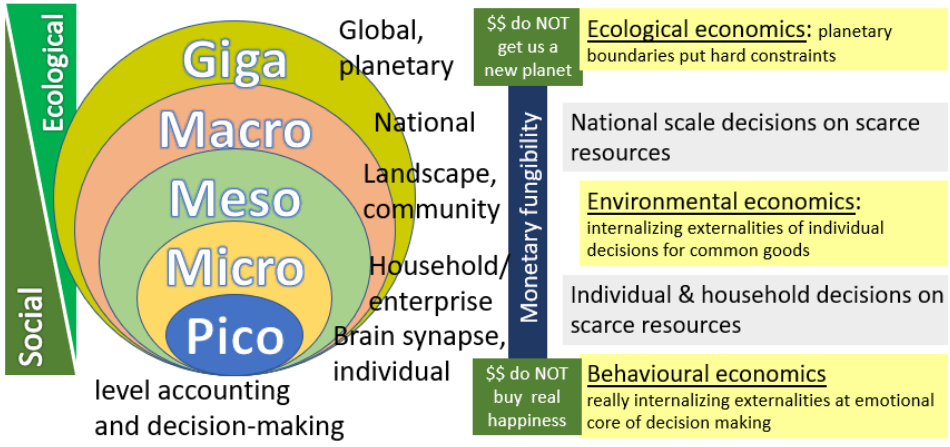
4.5 Understanding a 'policy-mix'

... in which aspects of regulation, incentives and motivation are designed with single policy objectives in mind, but jointly influence citizen decisions and choices, with risks of 'perverse incentives' and potential synergy.[106]



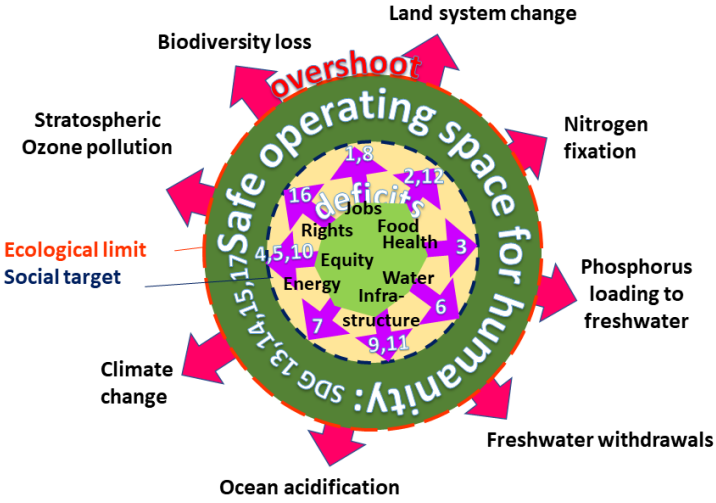
4.6 Five scales of economic analysis

… of human decision making in the face of scarcity and limited resources: Giga, Macro, Meso, Micro, Pico. They each have a specific type of Economics that aims to understand decision-making facing (scale dependent…) scarce resources.[90]



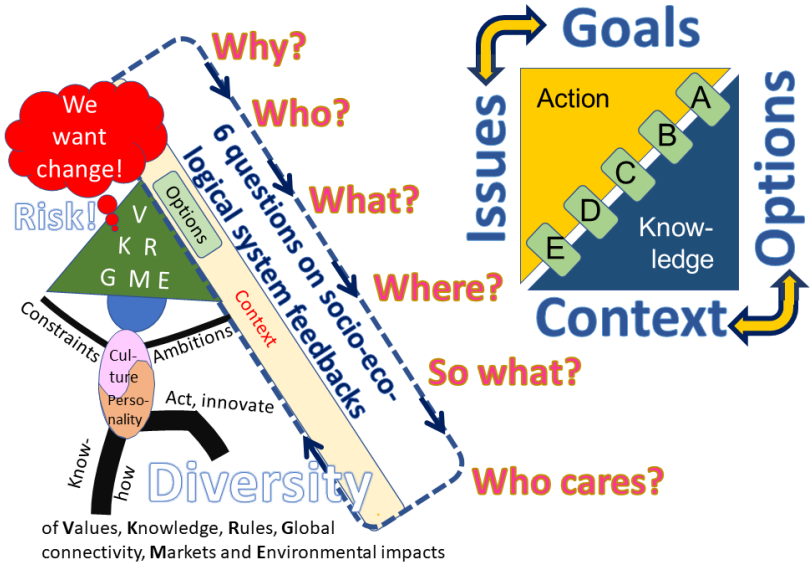
4.7 The doughnut challenge

… to define and stay within a safe operating space for humanity, not trespassing boundaries of planetary ecosystem functioning, but dealing with the existing development deficits, as specified in SDG's 1-12 and 16.[107]



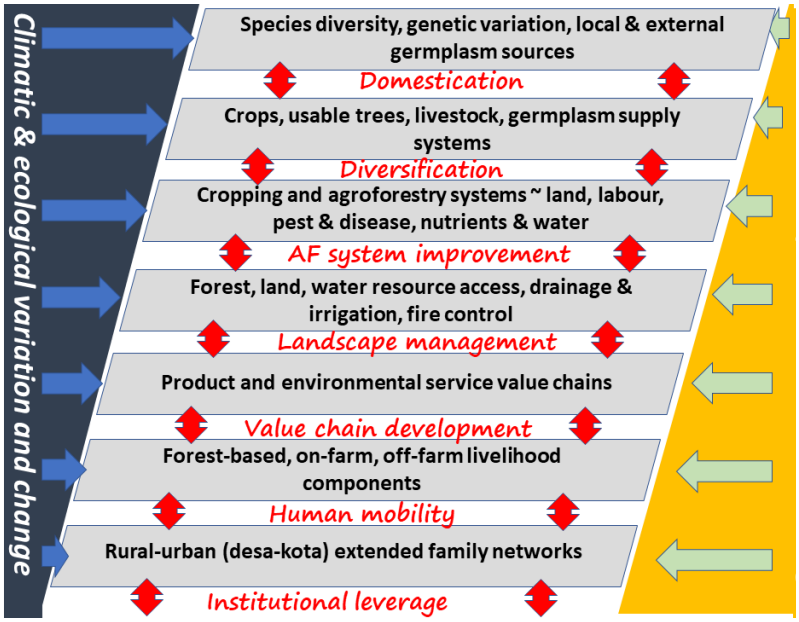
4.8 Boundary work

… to link knowledge (of options in context) with action (on issues and goals) by A. agenda setting, B. better understanding, C. coalitions for ambitious commitments, D. devolved (means for and of) implementation and E. evaluation (monitoring).[108]



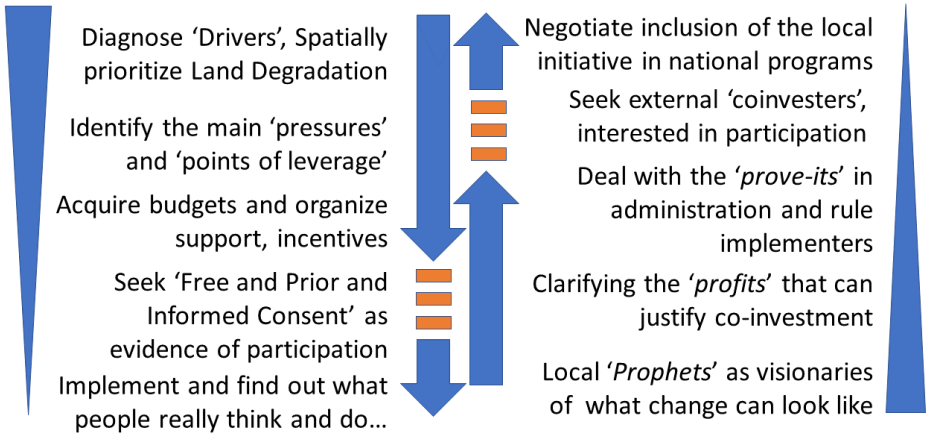
4.9 Ecological and Social aspects across seven landscape issues

… vary in their technical (ecological, biophysical) versus institutional (social, political) centres of gravity, even though for real-world impact they need to be approached coherently.[109]



4.10 Reconciling 'top-down'; and 'bottom-up'

… perspectives on land restoration requires that the role of visionary prophets, practical profit orientation and transparent prove-it agents all play their roles.[110]

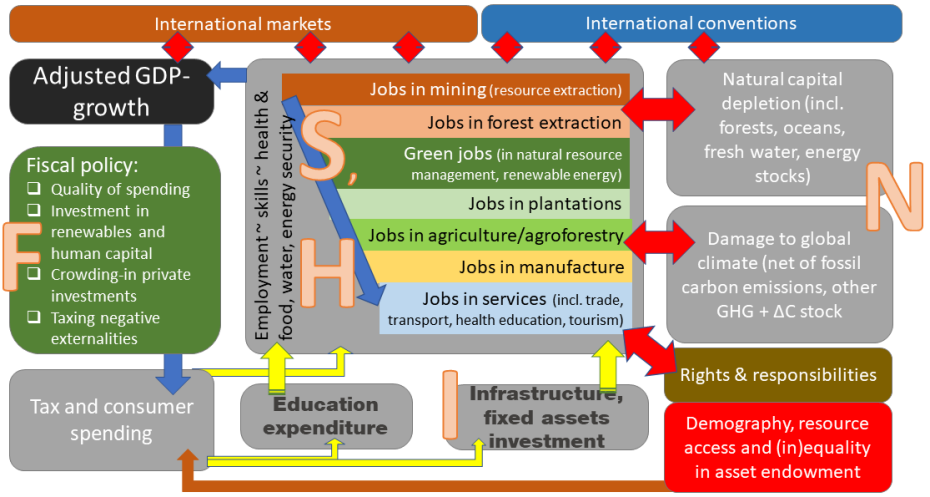


4.11 A map of 18 pathways to the eradication of extreme poverty

… through international agricultural research, as part of SDG agenda reconciled multiple theories of induced change.[111,112]

4.12 Capital interactions model of national policy options

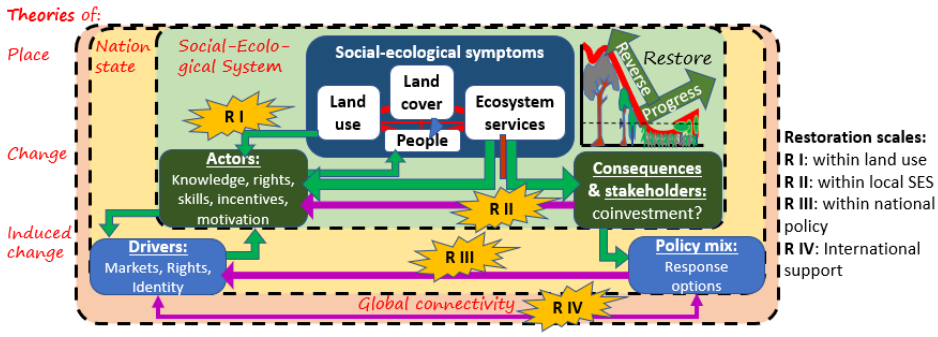
As all sectors in a national economy interact, planning policy leverage requires integrated models, way beyond applying green paint in an effort to 'greenwash'.[113]



Basic model of a national economy with policy leverage domains

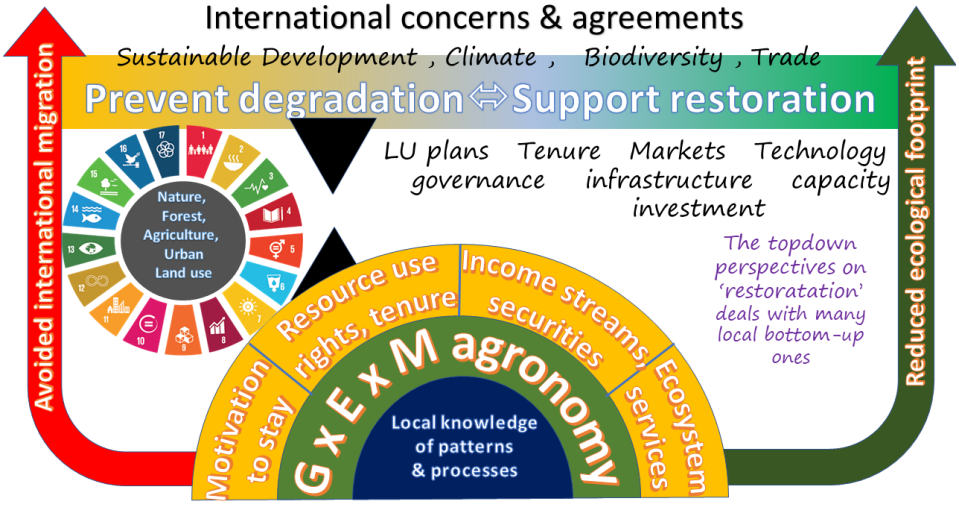
4.13 Restoration intensity

… can be classified by the scale at which interventions are needed to stop degradation and improve sustainability: I. within a land use system, II. within a landscape, III. within a national economy, IV. global responsibility.[114]



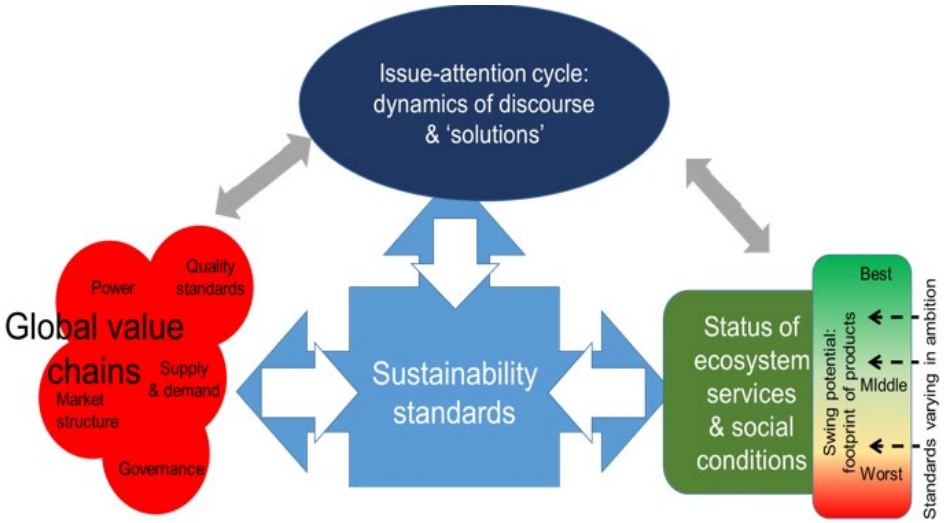
4.14 Tree crops as part of the land restoration debate

understanding genotype (G) x environment (E) x management (M) interactions as basis for in its link between local action and global concerns[10,53]



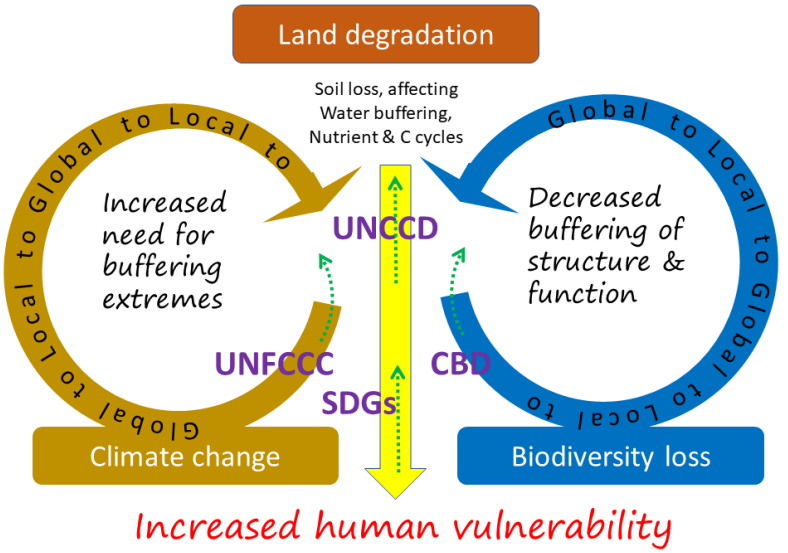
4.15 Certification

… emerges when consumers lose trust in either a product as such, or the social and environmental consequences of production, at predictable points along an 'issue cycle. While first 'shifting blame', publicly scrutinised standards can nudge towards safer, cleaner and fairer production.[115]



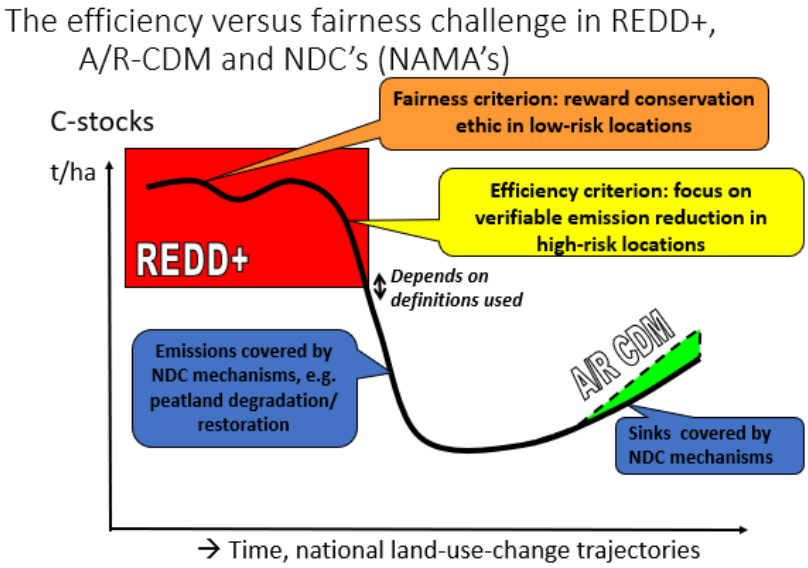
4.16 The common Rio agenda

… between the three global environmental conventions on land degradation (UNCCD), biodiversity (CBD) and global climate change (UNFCCC).[116]



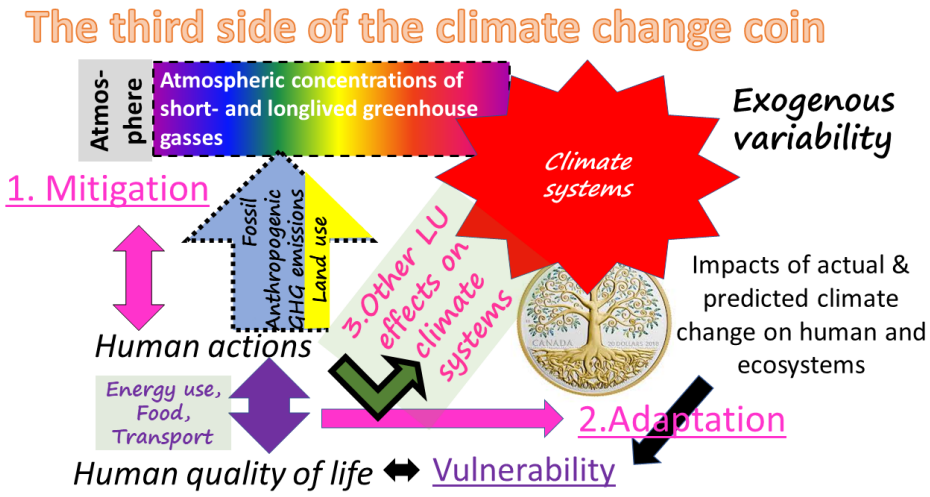
4.17 Reducing emissions from all land uses (REALU)

Investment in tree-based C sequestration, A/R-CDM, followed by REDD+ and NDC's, is still challenged by fairness vs efficiency considerations in global climate convention (UNFCCC).[117]



4.18 Land-use effects on hydro-climate

… complement mitigation and adaptation as the two main UNFCCC concerns as pathway to reducing human vulnerability.[118]

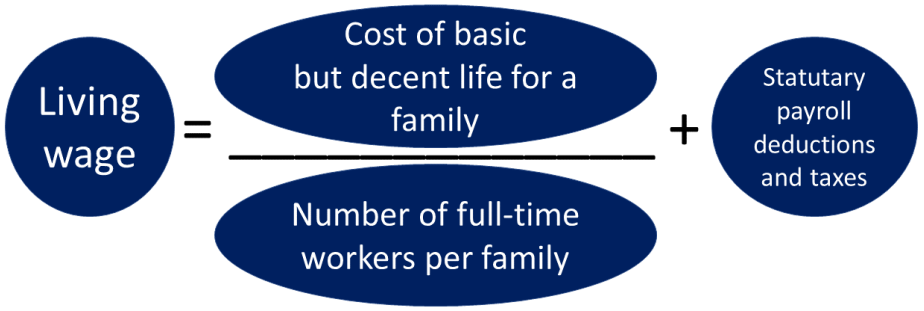


4.19 Zero-deforestation commitments

… are more easily made than transparently implemented. The higher the 'forest' threshold used, the less impactful the commitment is, as it allows conversion of 'degraded' forest.[119]

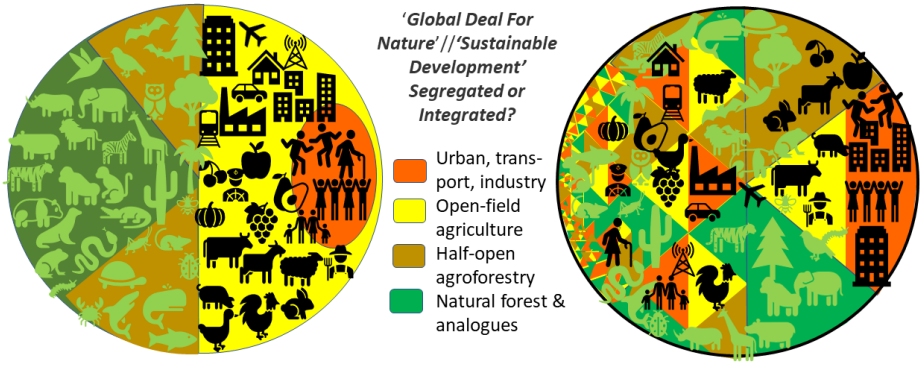
4.20 Living-wage commitments

… are now applied to producers of tropical tree crops. A number of cocoa producing countries now set national floor prices to provide a living wage for smallholders (of specified farm and family size). The concept of a 'just' wage has deep historical roots.[120]



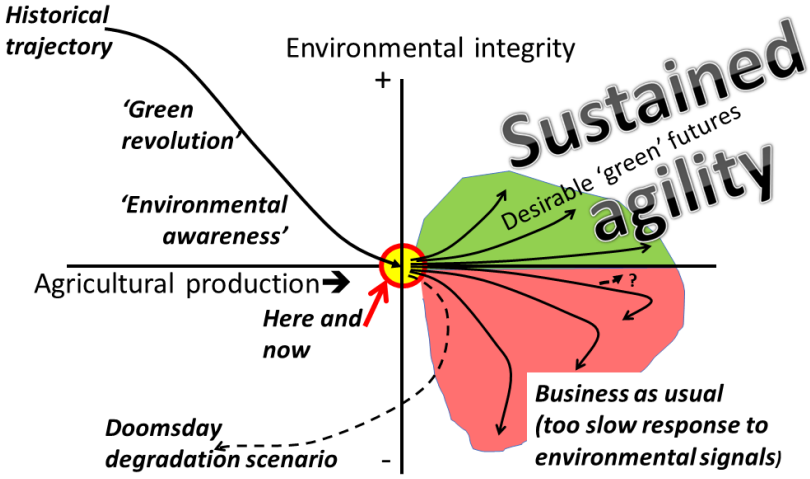
4.21 A proposed global deal for Nature

… will prioritize half the Earth for other biota than our own species. The opportunity for reconciling conservation and development goals may be larger in landscapes in which land units support multiple functions.[121]



4.22 The agenda for the Anthropocene

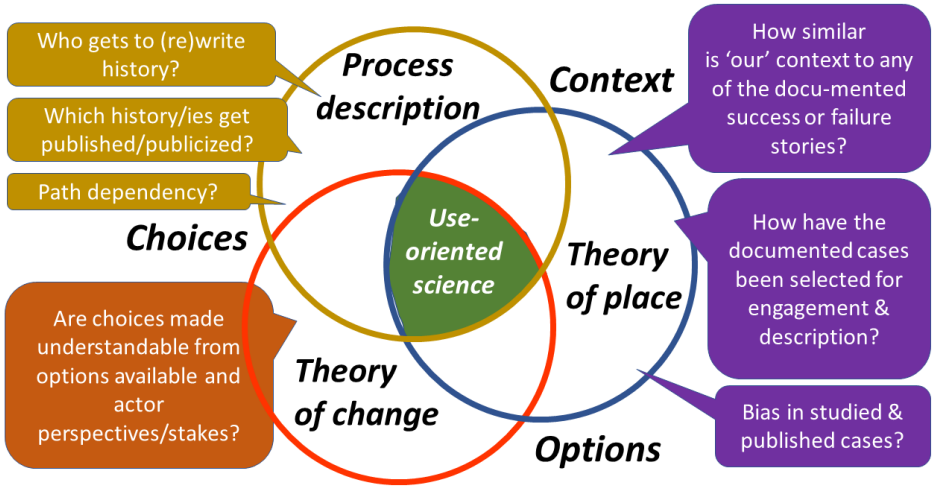
… requires sustained agility in restoring envirnmental integrity while minimizing development deficits.[122]



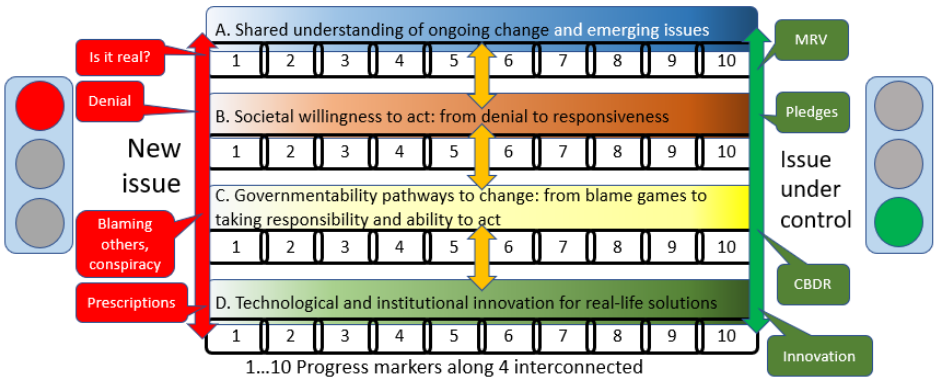
5

Discussion

All these concepts play in the background of every chapter, but human brains cannot deal with all this complexity at the same time, so the chapters follow a linear sequence and structure. We started with basic attributes of the various tree crops, the social-ecological systems in which they play a role and gradually moved towards the more policy-oriented perspectives on how negative futures can be avoided and positive ones brought within reach.



Despite the current opportunities for 'systematic review' of published literature, interpreting the evidence in the light of known bias in what gets published and what not, is still an art, rather than mechanical, fully replicable process.



1...10 Progress markers along 4 interconnected knowledge-to-action chains.

Identifying, addressing and overcoming the four types of constraint to effective, fair and sustainable solutions to emerging issues is like searching a four-leaved shamrock:

The traditional role of research is focused on leaf A only, but 'boundary agent' scientists can also contribute to the other three.

Table 1. Suggested progress markers for four interlinked 'knowledge to action' chains that govern the way 'issues' progress in social-political systems[118]

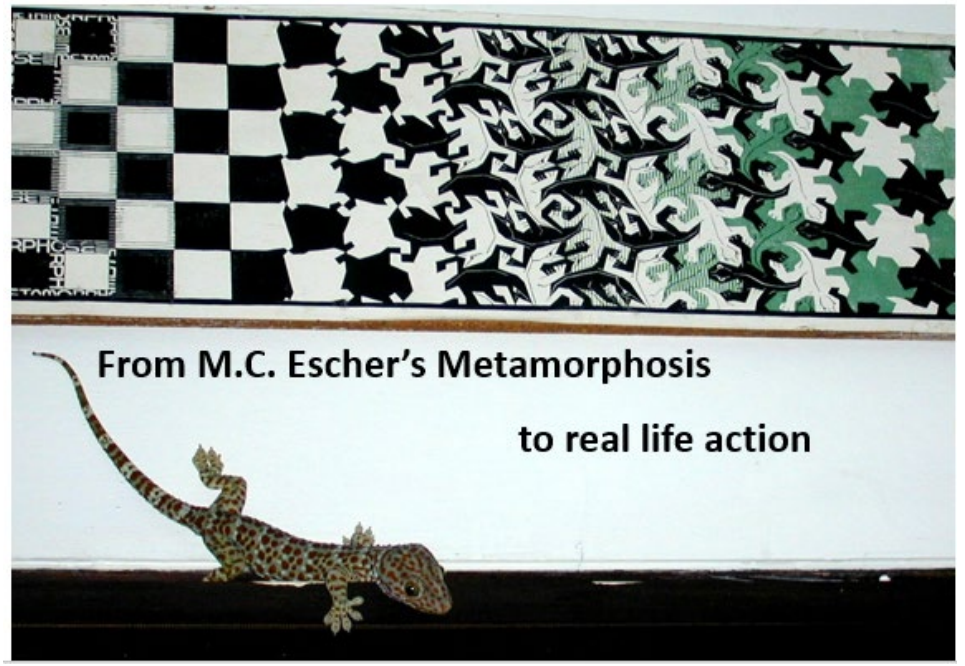
A. Science-based understanding of ongoing change and emerging issues	*B. Societal willingness to act: from denial to responsiveness*	*C. Governability pathways to change: from blame games to taking responsibility*	*D. Technological and institutional innovation for real-life solutions*
1. Initial guesstimates of seriousness of impacts of 'emerging issues' based on current understanding of 'systems'	1. Steps from 'ignoring' to 'denial', based on conflicting evidence from 'best' and 'worst' cases in public discourse	1. Moving from 'blame games' to identification of current rules, incentives and motivational instruments as contributors/ aggravators of the issue at stake, and options to reform them	1. Adequate grounding of potential innovators in existing knowledge and theories to explore new applications, and in lists of 'unresolved questions' for society at large

A. Science-based understanding of ongoing change and emerging issues	*B. Societal willingness to act: from denial to responsiveness*	*C. Governability pathways to change: from blame games to taking responsibility*	*D. Technological and institutional innovation for real-life solutions*
2. Operational definitions of the entities and processes associated with the 'issue' (potentially reframing, splitting and lumping of issues based on causation and/or effects)	2. Steps from 'denial' to accepting issues as part of the concurrent 'agenda', requiring debate in a multiple stakeholder context with multiple 'knowledge' claims	2. Reflection on an 'at least do no harm' precautionary principle in the face of remaining uncertainty and existing communication pathways with the wider stakeholder community	2. Safe spaces for innovators, in terms of resources (finances, facilities) needed and protection from micro-managers
3. Cause-effect mechanisms, feedback loops and system dynamics associated with the 'issue'	3. Steps from 'blaming others' and 'victim roles' to facing complex reality and taking shared responsibility	3. Path dependency of the issue and opportunities to deal with the established context and its spatial variation	3. Support for functional diversity of pathways explored, and delayed, stepwise selection of increased support for 'likely winners', within clear societal goals and criteria
4. Agreed methods with known biases to allow replicable research and mapping	4. Initial estimates of differential (by geographic and social strata) vulnerability	4. Relevance of and steps towards legal change in rights and responsibilities in the existing constitutional framing	4. Risk awareness and compliance with agreed safeguards by all innovators, but especially the publicly supported ones
5. Studies of spatial extent and temporal change of key aspects of the 'issue', its 'drivers' and 'consequences'	5. Initial estimates of differential contribution to 'causes' and likely need to change behaviour and/or pay for damage done	5. Economic (efficiency) dimensions of proposed pathways for dealing with the issue (at cause and/or consequence level)	5. Early awareness of scale relations (in applicability, undesired/unexpected consequences) of emerging innovations
6. Articulation of the planetary boundaries associated with the 'issue'	6. Initial estimates of differential opportunities to adapt to consequences and reduce contributions to 'causation'	6. Motivational and social (fairness) dimensions of proposed pathways for dealing with the issue (at driver and/or consequence level)	6. Effective two-way feedback where existing theory ('first principles') appears to contrast with emerging practices ('Pasteur quadrant')
7. Using understanding of non-linearity and feedback loops, propose 'thresholds' for 'safe operating space'	7. Articulation of culture- and religion-based motivation to act in solidarity or direct self-interest	7. Intersectoral integration across all relevant aspects of current agenda's (i.e. beyond the focal 'issue')	7. Early feedback from potential users and stakeholders of potential consequences that are to be avoided

A. Science-based understanding of ongoing change and emerging issues	*B. Societal willingness to act: from denial to responsiveness*	*C. Governability pathways to change: from blame games to taking responsibility*	*D. Technological and institutional innovation for real-life solutions*
8. Agreed monitoring, reporting and verification tools for collective action at relevant scales (local to global)	8. Dynamic coalitions for change in the face of tradeoffs and synergy with other issues in various stages of their own 'cycle'	8. Polycentric governance dimensions of rights and responsibilities across institutional scales	8. Opportunities to evaluate likely wider consequences in scenario tools that are sufficiently robust to extrapolate beyond known empirics
9. Scenario-evaluation tools to judge likely effectiveness of proposed and emerging innovations in their multi-dimensional characteristics (incl. tradeoffs and synergy)	9. Prioritization among concurrent issues and negotiated trade-offs between agendas of multiple negotiating parties	9. Opportunities for new public-private partnerships (covenants, phased change, clarity on long-term goals and standards)	9. Stepwise empirical tests at relevant scales for 'promising candidates', with clarity on standards to be applied for societal risk management
10. Regular re-assessment and recalibration of simplified proxies used for monitoring compliance and progress in dealing with the 'issue'	10. Sufficiently ambitious goals and adequate governance instruments (incl. monitoring compliance and effectiveness, sanctions) at all relevant scales in agreements and plans of action, with 'common but differentiated responsibility'	10. Where necessary, adjusting governance instruments on the basis of litigation by specific stakeholder groups	10. Adequate recognition (remuneration, influence) for past success (recognizing its limited predictive skill for future sucesses)

Using such scales to take stock of an issue in a given social-political-ecological context, will allow the evaluation of stepwise progress (or setbacks, as can happen) in relation to the involvement of 'agents of change', for a more realistic 'impact assessment', rather than claiming to 'solve' issues by any specific intervention. This might allow funding and activities to shift from the current focus on 'demonstrable and attributable impact' towards 'contributions to real problem solving' and agility.

The multitude of perspectives on tree-crop-based agroforestry means that the toolbox of research methods for current agroforestry research has expanded beyond recognition[123] in comparison with the early days of plot-level, replicated experiments aimed at establishing responses to management interventions in a specific location. The various chapters in the book review research with a fair sample of such methods, but more may be needed, whenever issues require so.


From M.C. Escher's Metamorphosis
to real life action

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Agroforestry with a strong market-oriented component of tree crops but also supporting local agroecosystem functions can be analysed and understood in multiple ways, building on many disciplinary traditions and using their terminology and concepts. Characterization of context and choices, plus understanding relationships and feedbacks is essential for appreciating 'options in context' and the way these change over time. Beyond observer roles, active engagement as agent of induced change to help make the world a better place has since long been the ambition of advocates of agroforestry. As a background to such endeavours , this publication introduces more than one hundred aspects, visually and with a short text, providing references to more specialized literature. Aspects include: A) Characterization of structure in existing land use can lead to a Theory of Place (ToP: patterns answering what?, where?, who? questions), B) Diagnosis of functions influenced by changing practices and systems can lead to a Theory of Change (ToC: patterns in answering how?, why?, since when?, so what? and who cares?), C) Assessments of leverage points for adaptive, transformative and re-imaginative change can lead to a project design Theory of Induced Change (ToIC), D) Research methods for ecological, agronomic, social, economic and policy-oriented research require clarity on units of analysis and scale relations of observable properties in relation to questions and hypotheses, and E) Guidance on how research methods need to match the stage of public issue cycle debate to contrib te to policy reform.

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