Agroforestry as innovation in tropical bioresource use

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Abstract. Indonesia not only has a rich biodiversity, it also has a rich tradition of local ecological knowledge and know-how of agroforests that blend the use of well-established crops, useful trees and understory plants of the local flora and the ecosystem engineers that maintain soil fertility and provide ecosystem services. Innovations need to match changing technical, social, environmental and economic expectations, norms and rules in societies – which may connect through global trade. Agroforestry involves the partial domestication of forest and agricultural resources. The agricultural-forest interface can be understood at plot/farm, landscape and policy levels. Tropical bioresources can be understood as nature living in, from, with and as people, as complement to the life value frames of people living in, from, with and as nature. This overview provides a number of frames that may help understand, appreciate and further enhance the processes supporting innovation.

1 Agroforestry and tropical bioresource use

Indonesia's rich biodiversity has over thousands of years spurned a rich tradition of local ecological knowledge and know-how of how to blend bioresourcs in different stages of domestication and management in 'agroforests' [1]. Described as 'domesticated forests', agroforests ecologically combine the use of well-established crops, useful trees and understory plants of the local flora, most of the local forest fauna and the ecosystem engineers that maintain soil fertility and provide ecosystem services. Socially, they are a way of life, often combined with hunting and gathering in a wider forest landscape, and intensive rice production in inland valleys. Problems started when such landscapes and integrated social-ecological systems became split into two parts: forest and agriculture, each with their own institutions, rules and academic research traditions. Current 'forest' definitions (FAO) exclude agroforestry, not based on thresholds for tree cover, structure, diversity, functions, services or values, but based on a 'non-forest' controlling agent.

Agroforestry, the study of the agricultural-forest interface (Figure 1) can be understood at plot/farm, landscape and policy levels [2]. While the plot-level interpretation of the word is still the best known, innovative contributions have been made and can still be furthered at

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landscape and policy scales, making tropical bio-resource use more effective, efficient and fair [3].

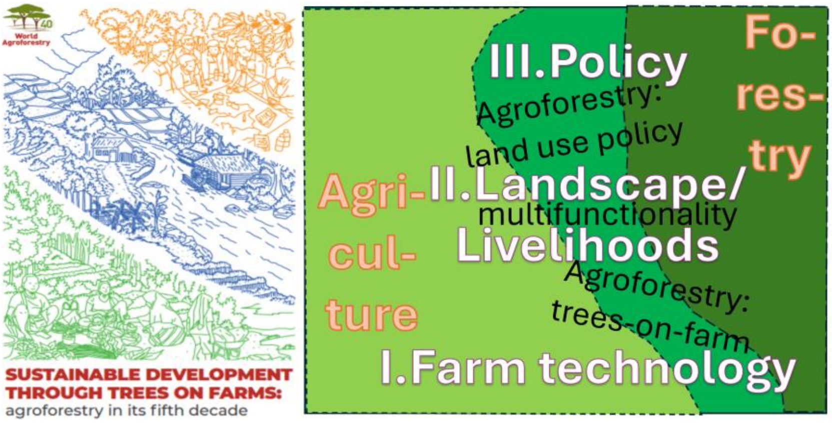

Fig. 1. Agroforestry has evolved by innovations connecting agriculture and forestry on three scales: plot/farm, landscape and policy.

Domestication, beyond the specific genetic selection of plants and animals, represents a major shift in the value of tropical bioresources. These values are appreciated differently for nature living ‘in’, ‘from’, ‘with’ and ‘as’ people, as complement to the life value frames of people living in, from, with and as nature [4].

2 Innovation as a process

Innovation is a mindset and skill, not a one-off accomplishment [5]. Innovation does not happen in a fully random world, without ‘persistence’ and ‘memory’. Innovation also doesn’t happen in a world where all existing rules are followed to the letter, and any deviation is frowned upon or worse. In between these two extremes, innovation can occur when the three basic conditions are met that Charles Darwin and Alfred Russell Wallace identified as basis for biological evolution: Replication (persistence) + Variation (deviations) + Selection (fitness). As the ’fitness’ depends on environmental context [6], several ways of classifying the social and environmental context offer insights into what type of innovation can emerge when and where in social-ecological systems. One of the oldest forms of agriculture is still the basis for many innovations. Where the demise of ‘shifting cultivation’ has been a recurrent theme in policy documents [7], innovations that support various pathways have been documented and analysed [8]. Pressure-induced innovation has become a common concept in agricultural systems [9].

This introductory overview provides a number of frames that may help understand, appreciate and further enhance innovations. Values of nature are ‘instrumental’ (especially in the ‘living from’ perspective, or the provisioning and regulating service categories), ‘relational’ (in living ‘in’ and ‘living ‘with’) and intrinsic (living ‘as’) [10].

The first concept (‘KRIMET’) recognizes the complexity of human livelihoods and decision-making (Fig. 2). At the heart of the flower is **Identity (I)**, where values are formed, transformed and used (subconsciously or explicitly) to make decisions, communicate with peers and shape communal decisions (e.g accepting, protesting or undermining decisions made at higher levels of human society). Relational (social) and instrumental (economic) rationality refer to processes in different parts of human brains [11]. Agroforestry is particularly rich at the instrumental and relational value interface [12], reflecting transitions between the life value frames of living in, from and with.

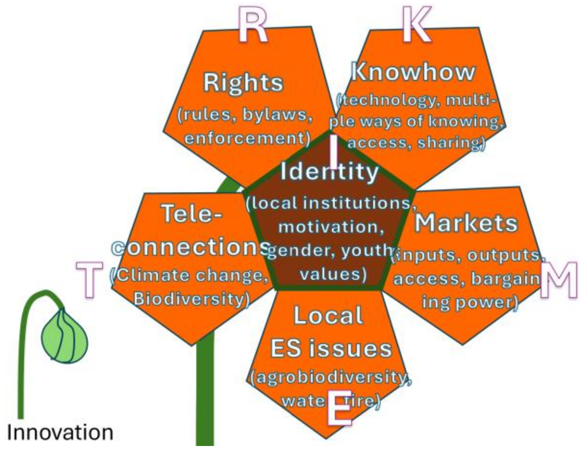

Fig. 2. Innovation, as the buds of flowers, needs to be aware of the multiple requirements for successful flowers with a chance to bloom.

Rights (R) refer to social norms of behaviour where a collective action can be ultimately called on to settle conflicts. In the institutional analysis tradition started by Ostrom [13], bundles of rights refer to various combinations of access, harvest, manage, modify, restrict, inherit and sell landscapes with bioresources, that are of interest to individuals, households, communities, the nation state and/or as global 'commons'. Rights often are a prerequisite for innovation, as analysed for example in the domestication of fruit trees [14] but can also be the primary target of institutional innovations facilitating development (e.g. SDG 16 [3]).

Know-how and knowledge (K) can be analysed as an interface of local ecological knowledge, often rich in detail on local resources, a modellers (or science-based) knowledge that is developing generic theories on processes, and a public/policy knowledge that sets rules to spatial patterns and defines categories of rights [15]. Domestication and tree diversity management integrates the three knowledge types [16].

Markets (M) trade-based exchange of tropical bioresources, involving long distances, existed long before agriculture, according to the archaeological record, but increased demand has been a major reason for shifting to greater control of growth and reproduction of bioresources, often adding specific quality characteristics desirable for consumers elsewhere [17].

Environmental effects locally (E) may often be directly linked to the water cycle and concerns of trustable drinking water [18]. Self-regulating local communities can be effective, but large-scale production and processing causes problems that require external regulation.

Teleconnections in climate change and biodiversity (T) connect stakeholders elsewhere on the globe to local resource use. Innovations need to match changing technical, social, environmental and economic expectations, norms and rules in societies – which in the case of global trade may connect through certification [19].

3 Social-ecological fitness of emerging innovations

Fitness or attractiveness of innovations can be based on the social or the ecological subsystem or their interactions (Table 1) and involves different subsets of KRIMET (Fig. 3). Innovation will have different emphasis in each phase of a 'resilience cycle', as has been explored in the response to the COVID pandemic [20] and volcanic eruptions [21]. The early stages of adoption (r-phase) may emphasize rapid growth, expansion and dispersal to new habitats. The saturation phase of approaching carrying capacity (K-phase) will emphasize resource use efficiency.

Table 1. Multiple ways of describing and classifying social-ecological systems as both context of and targets for ‘innovation’ as determinant of fitness

RIKMET (Fig. 2)	**Primarily social subsystem**	**Primarily ecological sub system**
RIK, ET	Nested systems pyramid: (((((((mindset), needs), rationa-lity), morality), sociality) status-power politics), culture and religion) [22]	Abiotic context, structure, function, ‘services’ from an anthropocentric perspective matching human needs
IM, ET	Life-value frames in human-nature relationship	Forest transition stages (in relation to human population density)
I, R K	Forest spirituality transition [23]	Resource appropriation and plant/animal domestication
KM, K	Generalist-Specialist dilemma in portfolio approach to risk management by diversity, incl. in market linkages, aware of boom and bust cycles [24]	Resilience cycle with r (expansion), K (saturation), Ω (crash), and α (reorganization) phases oof changing connectivity and stored capital
RIK, KET	Issue attention cycle, phases in public decision making	Landscape: terrain, water, soil, organisms (habitat and dispersal), fire, buffer, filter
K, K	Game theory at individual and social learning scales: learning styles	Models and ‘serious games’ for exploring landscape management scenarios

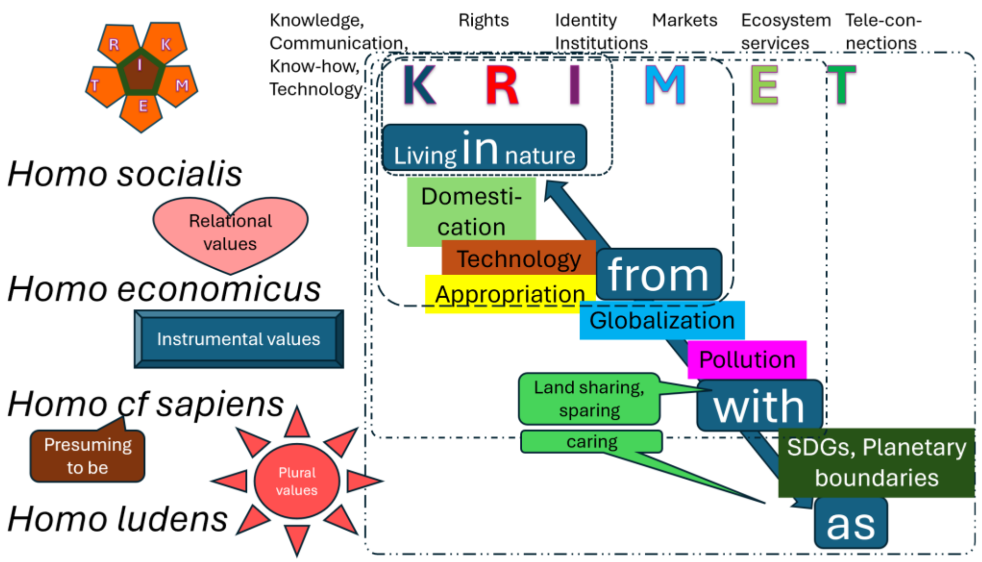

Fig. 3. Four broad aspects of human development reflect living ‘in’, ‘from’, ‘with’ and ‘as’ nature, with different weights for the identity, rights, know-how, markets, environmental impacts and teleconnections aspects for evaluating innovations.

The collapse phase (Ω) will benefit from reducing loss of stored capital and using safety nets. Finally, the re-orientation phase (α) will reconstitute systems from available components, matching a new situation. A more complete overview of concepts and methods [25] covers further ground.

4 Serious gaming as basis for innovation

Serious games have emerged as a powerful means of communication between landscape actors, if the games represent land use options and their hydrological consequences [26]. Two comparisons are now possible between pairs of games developed for a similar contexts. In Indonesia an individual-based game on Farmer Options and Risks in Complex Ecological-Social systems [*FORCES*; 27] can be compared with its landscape scale group-playing counterpart in the *H2Ours* game to explore Water Use, Resources and Sustainability [28]. In Kenya farmer decision making on water use in the '*Kilimo na maji*' game [29] can be compared with the 'Exploring New Gaming Approach to Guide and Enlighten' [*ENGAGE* 30] version that more explicitly includes conflicts and the ways these can be made worse or managed.

The main message of this paper that innovation as a process needs to be as a system-level emergent property that links diversity of resources, human adaptive capacity and flexibility to review and revise institutions to match changing conditions and opportunities.

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