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Ecosystem Services Functional Motif

a new concept to analyse and design agroforestry systems



Raffleau S.^{1,2}, Allinne C.^{1,2}, Barkaoui K.^{1,2,8}, Deheuevs O.^{1,6}, Jagoret P.^{1,2}, Garcia L.^{1,3}, Gosme M.^{1,4}, Lauri P.-É.^{1,4}, Mérot A.^{1,4}, Metay A.^{1,3}, Mézière D.^{1,4}, Saj S.^{1,7}, Smits N.^{1,4}, Justes E.^{1,2,9}

¹ UMR SYSTEM, Univ Montpellier, CIHEAM-IAAM, CIRAD, INRA, Montpellier SupAgro, Montpellier, France
² CIRAD, Montpellier, France
³ Montpellier SupAgro, Montpellier, France
⁴ INRA, Montpellier, France
⁵ CIRAD, CATIE, Turrialba, Costa Rica
⁶ CIRAD, Lima, Perou
⁷ CIRAD, Guyane, France
⁸ CIRAD, Rabat, Maroc
⁹ CIRAD, PERSYST Department, Montpellier, France

What is the ESFM concept?

Agroforestry systems (AFS) are multi-species systems comprising cropped and associated (spontaneous or not) species, including trees (Jose, 2009). Those species provide different types of supporting, regulating and provisioning ecosystems services (ES). We propose a new concept called **Ecosystem Service Functional Motif (ESFM)** defined as **the smallest representative spatial unit relevant to understand the provision of a set of targeted ES**, at a given time. The targeted ES can be of different types (habitat or support, production, regulation).

How to represent the ESFM?

For each targeted ES, the smallest unit at which the motif represents the field structural design is drawn. The ESFM is the smallest structural unit **providing ALL the targeted ES** (Fig. 1A & 1B). When the field structural motif has a simple geometric shape, then the ESFM has a simple geometric shape too (Fig. 1C : ESFM2 & ESFM3).

A new concept: what for?

1. To precisely describe a wide range of existing AFS, differing in terms of species richness, structural complexity and spatial organisation (Fig. 1). ESFM allows to determine the smallest scale at which data should be collected for relevant analysis and upscaling of AFS functioning.
2. To design improved AFS according to various types of targeted ES at various stages in the "life cycle" of the AFS (Fig. 1C);
3. To model AFS. Simple AFS (Fig. 1) generally have a simple geometric ESFM (rectangle, hexagon,...) which is easier to represent in models than when the ESFM has an irregular shape. In order to model complex AFS with irregular ESFM shape, we suggest to build simple geometric modelled ESFM based on a simplified structure including functions provided by groups of species (Fig. 2).

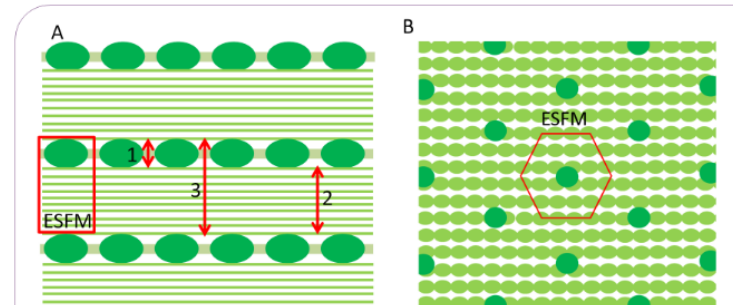


Fig. 1: ESFM (Surrounding redlines delimit ESFM in each example) is the smallest spatial unit providing all the targeted ES.

- Fig. 1A: simple alley cropping AFS in France. ESs = timber production + biodiversity conservation + habitat for natural enemies (1), + food or forage production (2), + soil C storage (3).
- Fig. 1B: Arabica coffee trees with erythrina in Costa-Rica. ESs = coffee production + N₂ fixation (CC mitigation) + Pests & diseases regulation

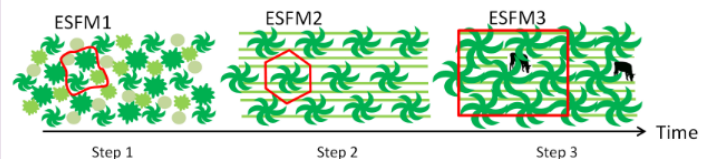


Fig. 1C : from left to right, ESFM transition in one decade: from food crop oil palm AFS to silvopastoral oil palm AFS in Cameroon (Raffleau 2008).

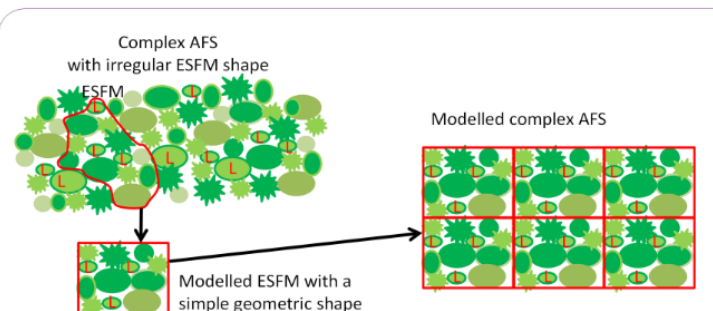


Fig. 2: The ESFM concept can help to model in complex AFS, like i) Melanesian food garden, ii) intensified temperate vegetables and fruits (horticultural) production, iii) African food garden, iv) West-Indies "Jardin créole", v) Cameroonian cocoa AFS (Jagoret et al.,2018), etc.

CONCLUSION & PERSPECTIVES

The ESFM concept can be applied to a wide range of AFS from simple to complex ones. The motif defines the structural and functional basic unit to be considered to target a given set of ES, at a given time.

The ESFM concept can be a tool for agronomists for (i) assessing the functioning of AFS with appropriate experimental design, (ii) designing improved agroecological systems explicitly based on ES targeted, and (iii) modelling AFS using a motif (or various motifs) adapted to represent the targeted ecosystemic functions and finally the provided services.

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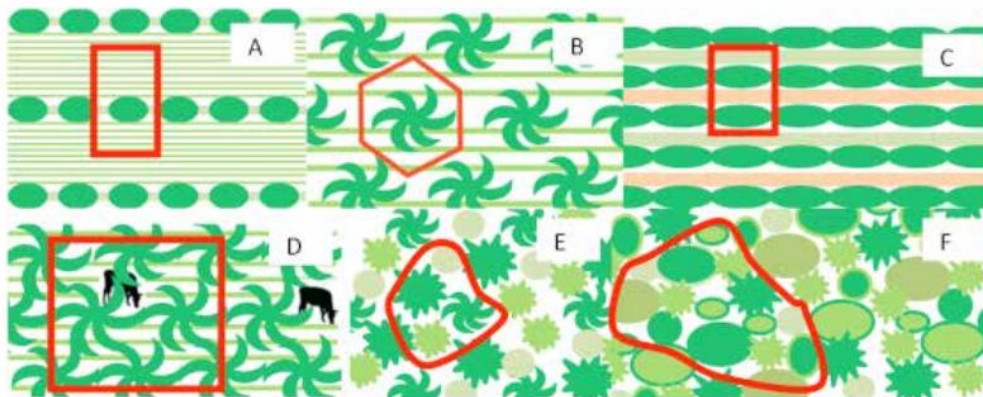
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Rafflegeau S.¹ (sylvain.rafflegeau@cirad.fr), Allinne C.², Barkaoui K.³, Deheuvels O.⁴, Jagoret P.¹, Garcia L.⁵, Gosme M.⁶, Lauri P.-E.⁶, Mérot A.⁶, Metay A.⁷, Mézière D.⁶, Saj S.⁸, Smits N.⁶, Justes E.¹

¹Cirad - UMR System, Montpellier, France; ²Cirad - UMR System, Turrialba, Costa Rica; ³Cirad-UMR System, Rabat, Maroc; ⁴Cirad - UMR System, Lima, Perou; ⁵Cirad - Montpellier SupAgro - UMR System, Montpellier, France; ⁶INRA - UMR System, Montpellier, France; ⁷Montpellier SupAgro - UMR System, Montpellier, France; ⁸Cirad - UMR System, Guyane, France

Agroforestry systems (AFS) are multi-species systems comprising cropped and associated spontaneous species, including trees. The species in AFS provide different levels of regulating, supporting and provisioning ecosystems services (ES). We assume that the provision of ES depends on the functional characteristics of all associated species and their spatial layout in the AFS, which we call here the “functional motif”. We propose the concept of Ecosystem Service Functional Motif (ESFM) defined as the smallest spatial unit that is relevant to understand the provision of all the targeted ES, at a given time. This ESFM is useful to determine the smallest scale at which data should be collected for relevant upscaling of AFS functioning. As a proof of the ESFM concept, we use it to describe existing AFS covering a wide range of species richness X spatial organisation. We show, for each AFS, the ESFM for various types of targeted (multiple) ES at various stages in the development of the system. We finally discuss the strengths and weaknesses of the ESFM concept for (i) analysing the AFS functioning, (ii) designing improved AFS according to ES targeted, and (iii) modelling such AFS.



Examples of ESFM in different types of AFS: simple AFS with tree rows and a single crop in the alleys (A, B), alternate interrows of service crops in vineyard (C), silvopastoral AFS (D), complex AFS (E) and home garden (F). Surrounding redlines delimit ESFM in each example.

Keywords: Agroforestry, agroecology, functional pattern, system design, ecosystem services.