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Biophysical criteria used by farmers for fallow selection in West and Central Africa

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ABSTRACT

In many parts of the humid Tropics, slash and burn shifting cultivation, incorporating a fallow phase, is the most common farming method, encompassing a broad diversity of techniques. The ecological productivity and sustainability of such systems depend upon the crop:fallow time ratio. Farmers often have biophysical criteria by which to match parcels to cropping systems and decide, for example, when to recultivate a fallow. In this paper, we collate reports of indicators used by farmers to aid in fallow choice from across the agronomic, forestry, ecological, and anthropological literature.

We found 27 examples of farmers using such biophysical indicators. Examples found were from eight countries across West and Central Africa. The literature review showed that farmers rank fallow age usually first, followed by vegetation composition, the presence of indicator plants, and earthworm casts. 53 indicator plant species were identified across the region of which 37 were said to indicate soil fertility, 13 soil infertility and 3 either fertility or infertility, depending on their growth characteristics. The most exhaustive lists of indicator plants were reported from southern Cameroon, the Ashante region of Ghana and south west Nigeria. *Chromolaena odorata* was the most frequently mentioned plant indicator species. The trees *Triplochiton scleroxylon* and *Terminalia superba* and the grass were each mentioned, generally as soil fertility indicators, in three areas. Other species mentioned multiple times were *Aframomum* sp., *Andropogon gayanus*, *Ceiba pentandra*, *Milicia excelsa*, *Triumfetta cordifolia* and *Trema guineensis*.

Farmers in West and Central Africa have identified indicators for selecting which fallow plots to recultivate. Fallow age, vegetation composition, the presence of indicator plants, particularly *C. odorata*, and earthworm casts all have some logical scientific basis and farmers observations are supported by the results of scientific studies. There is a lack of documentation of farmers' knowledge and more studies should be conducted. Such knowledge should form the foundation of any suggested interventions in farming systems in the region and provide information to farmers in communities where such knowledge is not currently applied.

1. Introduction

In many regions of the humid Tropics, slash and burn shifting cultivation is the most common farming method. Farmers clear, burn and crop a small area of forest or bush fallow. After cropping, the land is abandoned to "fallow", the successional vegetation that follows the cropping phase (Ewel, 1986). After a variable fallow length, the crop:fallow cycle is repeated. The productivity and sustainability of this system are assumed to depend upon the crop:fallow time ratio (after Guillemin, 1956). Fallows regenerate soil fertility, act as a weed-, pest- and disease-break, accumulate biomass, provide wood, green manures, forage and other goods and their properties partially determine future crop yields. A given system has an optimum fallow period for production, longer fallow periods are unnecessary, and shorter fallow periods lead to a decline in productivity (Guillemin, 1956; Mertz, 2002).

In parts of the humid forest zone of West and Central Africa, the area in fallow greatly exceeds that under in crop production at any particular time (Hauser and Norgrove, 2013). In southern Cameroon, for example, the area of land in various stages of fallow is 3.58 times greater than that under food crops, including perennial food crops (calculated after Nolte et al., 2001). Thus farmers can choose plots to cultivate, within the general constraints of land tenure laws. There can be conflict between customary and formal law. For example, in Cameroon, formal law limits local access to

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forested land (Sunderlin et al., 2014). Cropped land near villages is usually undisputed, yet areas further away, particularly fallows, are often contested (Russell et al., 2011). Aspects such as household wealth and thus size of land-holding will influence the amount of choice available to farmers (Gleave, 1996). Apart from these and other social and gender-related issues (Grigsby, 2004), criteria used by farmers include travel time to site (Wilkie and Finn, 1988) and other location factors such as proximity to a road (Gleave, 1996) and to the household's other fields (Brown, 2006). Labour availability is also a criterion (Richards, 1986, quoted in Ickowitz, 2006). However, assessments of potential productivity are critical in the process of site selection (Gilruth et al., 1995).

With increasing population mounting the pressure on land resources, there is a need to develop indicators of the restoration of soil fertility in fallow systems. There are few reports in the literature of fallow indicators used by farmers. Steiner (1998) working in Rwanda reported that 30% of farmers used indicator plants in fallows. Styger et al. (2007) described the detailed characterisation of fallows by farmers in the Betsimisaraka region of Madagascar. Tanaka et al. (2007) described the use of plant indicator species used by the Iban of Sarawak to distinguish between suitable and unsuitable sites. Thein and Minn (2007) mentioned which plants indicated fertile soils in Karen swidden systems in Myanmar. Marquardt et al. (2013) documented a range of fallow properties described by farmers in the Peruvian Amazon to distinguish "good" from "bad" fallows. There are few and albeit scattered reports documenting indicators used by farmers in the West and Central African region.

The objectives of our research were to gather information on biophysical indicators used by farmers to decide when to recultivate a field, to verify to what extent they were valid and to make recommendations on their usage. We focused on the humid forest and forest–savannah transition zones of West and Central Africa given that in this region population density and pressure on land is still sufficiently low that fallowing is practised. Farmers have little access to agricultural extension services for advice so often rely on traditional local knowledge, although due to the high ethnic and linguistic complexity of the region (Michalopoulos, 2012), knowledge diffusion may be limited. Compiling indicators from across the region may thus provide useful information to farmers in comparable biogeographic areas.

2. Materials and methods

We conducted a narrative literature review, collating reports of indicators used by farmers to either aid in fallow choice from across the agronomic, forestry, ecological, and anthropological literature, in English or in French. We included journal articles, books, available grey literature sources and online theses within an unlimited timeframe. We restricted our geographical area to the humid forest and moist savannah agroecosystems (*sensu* Jalloh et al., 2012) of West and Central Africa, ranging from Guinea Bissau in the west to the Democratic Republic of Congo (DRC) in the south-east. Major soils in the region include Oxisols, Ultisols, Alfisols, Entisols and Andisols. References comprised those studies where quantitative surveys had been conducted and also those that simply reported qualitative observational data directly from farmers. We excluded any reference that did not state from whom the indicator was obtained and we also only reported indicators used by farmers. Where results from a single study in a single area were reported in multiple articles, we treated them as a single report. We do not report primary data in this study. Botanical nomenclature was verified using TROPICOS of the Missouri Botanical Gardens.

We found 27 examples of reports of farmer use of indicators comprising 19 journal articles, 2 books, 4 theses and 2 grey literature sources of which one originates from the authors (Birang et al., 2003a). Of these, 7 considered only soil indicators and 7 considered only plant indicators; the remaining 13 reports dealt with all possible indicators. In comparing the relative importance of all indicators, we therefore only considered results from the 13 latter remaining reports as inclusion of all ($n = 27$) would have biased the results. Examples found were from eight countries: Sierra Leone, Côte d'Ivoire, Ghana, Benin, Nigeria, Cameroon, the Republic of Congo and the Democratic Republic of Congo (DRC). 54% of reports either conducted interviews with farmers or used an adapted version of a local game 'bao' (Brown, 2006), fully described in Franzel (2001), to obtain information. The number of farmers questioned (n) ranged from 13 to 600 with a median of $n = 91$. The remaining 46% of reports did not specify the methodology used. 75% were from the humid forest zone and 25% from the forest–savannah transitional zone. We discussed findings by comparing them with the results of experimental studies in the region with some being those of the authors.

3. Results

On average, farmers used 2–3 indicators to determine when to recultivate a fallow. Across studies, excluding those that only asked about specific classes of indicators (only soil fertility or only plant indicators), the most frequently mentioned indicators were the presence of indicator plants; fallow age; the presence of dense trees/ground shade, and vegetation composition (Table 1).

Four reports ranked the indicators used by farmers to determine when to crop a fallow. Here, vegetation descriptors predominated with fallow age most frequently ranked first, followed by vegetation composition, the presence of indicator plants, and the presence of earthworm casts (Table 2).

Of the six studies dealing exclusively with soil-based indicators, those most frequently used were the presence of earthworm casts and soil colour, followed by soil structure/hardness and texture (Table 3). Earthworm casts were ranked as the fifth most frequent criterion of all types of parameters (Table 1).

53 indicator plant species were identified across all studies (Table 4). 37 plants were used as indicators of soil fertility and thus to cultivate the fallow. 13 plants indicated infertility and thus to avoid cultivating the fallow. 3 species indicated either fertility or infertility, depending on growth characteristics. The most exhaustive lists of indicator plants were reported from southern Cameroon (Carrière, 2002a,b; Carrière et al., 2002; Castro Carreño, 2001, quoted in Carrière and Castro Carreño, 2003), the Ashante region of Ghana (Dawoe et al., 2012) and south west Nigeria (Osunade, 1992).

The most frequently mentioned indicator plant species, listed in 10 areas (8 times as a soil fertility indicator, once as an indicator of infertility and once as either an indicator of fertility or

Table 1
Percentage frequency of inclusion and consequent ranking of indicators used by farmers for fallow selection. $N = 13$.

Attribute	% reports listing indicator	Rank
Presence of indicator plants	85	1
Fallow age	46	2
Presence dense trees/ground shade	31	3
Vegetation composition	23	4
Presence of earthworm casts	15	=5
Perceived time to dry	15	=5
Fallow estimated biomass	15	=5
Thickness of litter layer	15	=5
Soil colour	15	=5

Data sources: Adou Yao and Roussel (2007), Almy et al. (1991), Benneh (1972), Birang et al. (2003a), Bolakongo et al. (2013), Brown (2004), Henry (1979), Jurion and Henry (1967), Osunade (1992), Richards (1986), quoted in Ickowitz (2006), Richards (1985), quoted in Gleave (1996), and Tshibaka (1989).