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CORRIDOR

Working group on evaluation and synthesis of information on tree cover to balance productivity and biodiversity in agricultural landscapes along the Mesoamerican Biological Corridor

Specific Support Action

Integrating and strengthening the European Research Area
Priority A2 Rational use of natural resources

Deliverable 3. Protocols for collecting and interpreting data on tree cover in pastures

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Dissemination Level		
PU	Public	PU
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This protocol suggests minimum requirements for collecting and presenting data for research on effects of integrating trees within pastures on productivity and biodiversity along the Mesoamerican biological corridor. It has four sections one each on key requirements for data on tree cover, productivity and biodiversity and a final section on presentation and interpretation of data. Issues of on the co-location of studies and priorities for research are covered in the regional research strategy (Deliverable 6).

1. Tree cover

The adoption of standardized methodologies for tree characterization at both the landscape and plot level will greatly enhance the quality of scientific information available and facilitate the synthesis and analysis of tree cover information across pasture dominated landscapes in the region (see review of research in Deliverable 2). A list of key information that these studies should systematically collect is given in Table 1.

Table 1. *Standardized set of information that should be included in studies of tree diversity in pasture-dominated landscapes (*indicates data that is desirable but not required).*

Plots	Timing	Landscape context	Data on individual trees	Data summary
Plot size	Dates of study	Name of town and province (preferably with a map)	Minimum tree diameter (e.g., dap> 2.5 cm, or dap> 10 cm) or tree height surveyed	# of trees sampled (per land use type and per landscape)
Plot location (GPS)	Season (rainy, dry, transitional)	Holdridge life zone	Tree heights	# of tree species found (per land use type and per landscape)
How plots were selected (random, systematic, etc.)	Type of study: one-time characterization or repeated surveys	Size of landscape (ha)	Tree diameters	Tree density (trees per ha)
Number of plots surveyed and spatial arrangement in the landscape	Climatic data (mean precipitation, mean temperature)	% of landscape under pasture, forest, crops and other land uses	Tree species	% of pasture under canopies of
Map of plot arrangement within landscape (relative to other land use elements)		History of landscape use (years since deforestation)	Tree crown size	Overall mean tree height (± SE)
		Type of cattle production (milk, dual purpose, meat, etc.)	Tree phenology (fruiting, flowering, deciduous, etc.)	Mean tree height (± SE) per land use type and per landscape
		Grass species present in plots (dominant species and type-naturalized, exotic, mixture)	*Maps of tree location within pastures, including spatial distances between trees and other landscape elements	Appendix with full list of species encountered and relative abundance (to allow for generation of species-area curves and graphs of rank-abundance)
		Detailed definitions of all land use types studied (including information on age, height, minimum size, dominant species, management	*Canopy density / shade cast by trees either using in order of preference direct measurement of PAR above (open) and below crowns, hemispherical photographs or densiometer	Indices of tree diversity and evenness per plot, land use type and landscape

2. Tree, pasture and animal productivity

Productivity in silvopastoral systems has four principal dimensions: wood (accumulated stem growth of the tree component); tree fodder (regularly browsed or harvested tree parts, mainly fine branches, leaves, pods and fruit); the herbaceous pasture (as affected by the presence of trees) and finally the livestock who consume the fodder resource and produce the major output of the system as animal products (principally in the present context, milk and meat). We concentrate here on the fodder resource (tree and pasture) and how it is utilised by animals, with a focus on better understanding the impact of trees on overall livestock production. Standard methods exist for many aspects of these measurements and can continue to be used without further advice here, but there are key areas where application of more robust data collection methods are urgently needed, particularly for pasture productivity.

Assessment of overall productivity requires combining animal growth and production measurements with tree growth and production measurements. Pasture and browse productivity are intermediate variables and may be measured:

i) to better understand what contributes to overall productivity,
ii) where an intermediate assessment is more cost effective or pragmatic than assessing animal production directly, or
iii) to assess the additive effect of trees on pastures where animal productivity measurements are not possible.

2.1 Trees

Mensuration methods for agroforestry trees have been reviewed and standards established (Stewart and Salazar, 1995). Depending which uses (e.g. timber, firewood, fodder, fruit) are relevant for the species to be inventoried the appropriate guidelines for measurement should be followed. We therefore recommend a two stage approach:

i) survey local knowledge to ascertain uses of species occurring on pastures
ii) for each use category, follow the guidelines for assessment set out in Stewart and Salazar (1995).

2.1.1 Biomass and wood

There are already ample guidelines for assessing tree growth and timber resources in Mesoamerica (Salazar, 1989), including within silvopastoral contexts (the guidelines for tree inventory in Table 1 specify standard measurements for characterising tree cover, these can be coupled with destructive and/or non-destructive measurement of biomass accumulation as set out in Steward and Salazar, 1995 and Section 2.1 above).

2.1.2 Tree fodder

Measuring biomass production and its partition to edible leaf and fruit components can be achieved using standard multipurpose tree mensuration methods (see Section 2.1.1 above). Assessing how much tree biomass is consumed by animals in field browsing contexts is readily achieved using the n-alkane method (Dove and Mayes, 2006) or other observational methods in situ (Harrington and Wilson, 1980). Nutritive value of fodder per unit of biomass is best assessed using feeding trials but can also be assessed using chemical analysis as set out in Preston (1995), in which case, for tree species, anti-nutritive factors require careful evaluation, in addition to standard measures of digestible energy and protein. It is important to capture phenology of production, particularly where there is strong seasonality and so annual cycles need to be appropriately sampled.

2.2 Pasture

Often standing biomass of pasture has been measured and reported as productivity. This is unhelpful because pasture productivity actually refers to growth over a specified period of time, usually expressed per day. Comparative standing biomass measurements (for example, under and away from tree crowns), can represent a legitimate comparison if grazing has been prevented (either completely or using exclosure cages to protect a measurement area). Standing biomass in grazed pastures without use of exclosures, even if made periodically, are not interpretable in terms of productivity because pasture growth cannot be separated from how much has been grazed over the assessment period.

Ecologists favour measurements of primary productivity, often focussing on above-ground components for simplicity but for silvopastoral systems the most appropriate measure relates to production above the grazing height of the livestock concerned. We recommend the use of standard cut quadrats for productivity measurement (Stockdale and Kelly, 1984). Exclosure cages that are cut to grazing height, allowed to grow, and then re-cut to the same grazing height, yield an appropriate harvested biomass for productivity assessment over the growing period between cuts. The size and number of cages required for a particular pasture depends on the growth form and variability of the pasture, so this needs to be assessed to calculate the appropriate sampling density. The frequency of cutting depends on the growth rate but needs to be frequent enough to mimic grazing (usually two to four weeks is appropriate). Nutritive value of harvested biomass can be assessed, as set out for browse in Section 2.1.2 above. While a bulked sample may be used, separation of the pasture to species level is desirable both to record botanical diversity and relate nutritive value to pasture components.

2.3 Livestock

Cattle are the major livestock category within Mesoamerican pastures and so we concentrate here on cattle productivity as the vehicle for comparative purposes along the corridor.

Beef, dairy and dual purpose cattle production systems are operated along the MBC. Measurement of milk production is the most sensitive tool for exploring relationships between tree cover and productivity because of the short response time over which measurements can be made but it is also the most labour intensive tool and needs to be coupled with liveweight measurements at the beginning and end of measurement periods. Liveweight gain (or loss) in growing animals and carrying capacity for fixed sward height maintenance for whole herds or specific classes of stock are often more practical over seasonal cycles. Where comparisons are made across pastures it is important to ensure comparability of livestock breed, size and grazing pressure (controlled by sward height assessment). Measurements should follow standard animal production protocols as set out in t'Mannetje and Jones (2000).

3. Biodiversity

A complete inventory of biodiversity requires consideration of trees, pasture and fauna both above and below ground. Trees are covered in Section 1 above and pasture composition (including spontaneous herbaceous species) in Section 2.3. In general, the diversity of grazed pasture, is more of an issue for productivity than biodiversity, since grazing modifies pastures to a very great extent. It is also important to measure faunal diversity in landscape elements (as identified in Section 1) that may have lower grazing pressure or livestock exclusion but are nevertheless part of the overall diversity supported by the landscape. This should be done with standard botanical quadrat survey at a sampling frequency appropriate for the variability encountered (Bonham, 1989). Belowground biodiversity is a key emerging area associated with sustainability of pasture ecosystems and the provision of ecosystem services. This project did not specifically focus on soil biota but there is a major global initiative to develop a handbook on methods for assessing belowground biodiversity that will cover all major functional groups of organisms (Moreira et al, in prep) and we recommend following the protocols set out therein.

The most common and comparable biodiversity measurements are of above ground animal taxa – particularly with a focus on rare and endangered or forest dependent species. A list of the types of information that should be routinely collected within studies of animal diversity in pasture-dominated landscapes are set out in Table 2.

Table 2. *Standardized set of information that should be included in studies of animal diversity in pasture-dominated landscapes.*

Information on survey sites	Information on timing of study	Information on landscape	Major methods used for each taxa[1]	Types of data to collect	Data summaries
Plot size	Dates of study	Name of town and province (preferably with a map)	*Mist-netting studies:* number of mist nets, heights and lengths of mist nets, location and arrangement of mist nets (including distances between nets), hours of net operation (and total # hours open), whether animals are marked or ringed to allow recognition	Abundance	# of animals sampled (per land use type and per landscape); rank-abundance curves
Plot location (GPS)	Season (rainy, dry, transitional)	Holdridge life zone	*Point count studies:* number of points, radius of point count, location and arrangement of point counts, distance between point counts, time spent at each point count and whether point count data include only observed birds or also birds that were heard	Species richness	# of species registered and estimated species richness(per land use type and per landscape) ; species area curves ; diversity (Shannon, Simpson) and evenness indices ; species composition
How plots were selected (random, systematic, etc.)	Type of study: one-time characterization or repeated surveys	Size of landscape (ha)	*Pit-fall traps:* trap design, number of traps, mesh size, type and amount of bait used, location of traps, distances between traps, frequency of trap revision, time traps are open	Behavioral data of individual animals: mating, feeding, foraging, nesting, etc.)* Data on which tree species animals feed/nest/roost/ or perch on	% and number of animals and species exhibiting different behaviors (e.g., mating, nesting, foraging) within individual habitats;
Number of plots surveyed and spatial arrangement in the landscape (including distances between plots)	Climatic data (mean ppt, mean temperature)	% of landscape under pasture, forest, crops and other land uses	*Netting along transects:* Length and width of transect, time spent netting,	Demographic data: Birth rates, death rates, immigration rates and emigration rates	Animal density and population size, Population trends (growth/decline/stable); birth and death rates, immigration and emigration rates
Map of plot arrangement within landscape (relative to other land use elements)	Length and timing of study (dates/months)	History of landscape use (years since deforestation)	*Telemetry:* number of organisms tagged, type and size of transmitter, distance over which radio transmitters are detected, length of telemetry study, frequency of observations,	Biometric information: Animal size, weight, length**, reproductive condition, age, sex	Biometric characteristics of populations and by sex, age or size distributions, % in reproductive condition, male/female ratio, etc.
		Type of cattle production (milk, dual purpose, meat, etc.)	*Sherman and Tomahawk traps*: Number of traps, trap size, trap placement, distances between traps, bait used, frequency of trap revision	Movement data (for telemetry studies): distances moved while feeding; dispersal distances of juveniles, etc.	Home range size, distances traveled (daily, monthly), frequency of movement, rates of movement between different habitat types, distances dispersed by juveniles
				Migration patterns (dates of arrival/departure for migratory animals and directions of movement)*	Departure dates for individual species

* Optional data that would be useful to collect but is not critical for understanding general patterns of diversity
** There are many standardized biometric measurements used for different taxa (e.g., birds: body weight, wing and tarsus length; bats: body weight, wing length).

[1] Standardized methods that exist for most taxa should be followed, e.g., ants (Agosti et al., 2000), birds (Bibby et al., 1992), mammals (Wilson et al., 1996), amphibians (Heyer et al., 1994).

4. Presentation and interpretation of data

The most valuable data sets for exploring thresholds of tree cover for productivity and biodiversity in pastures are those where both productivity and biodiversity are assessed at the same time across a range of tree cover densities. These are very rare, so presentation of partial data on some of these aspects in standard and generally interpretable forms will allow greater comparability amongst sites and studies.

Tables 1 and 2 above set out how tree cover and animal diversity data should be presented and summarised. Key areas of importance derived from the review of existing data (in Deliverable 2) are as follows.

1. Presentation of rank abundance data rather than, or in addition to, diversity indices for plant and animal taxa. This is of key importance because indices conflate abundance and species richness so that similar values of the indices can arise from very different disaggregated data whereas rank abundance data are directly comparable.
2. Transparency and clarity of method. Despite the existence of standard protocols for measurement, these are inevitably adjusted to suit the nature of specific sites and studies making it vital for the precise methodology used for each measurement to be clear.
3. For comparisons amongst biodiversity measurements, equality of sampling effort is of critical importance, this requires presentation of data (as appendices if not in the main body of an article) including a full list of species and their relative abundance in each tree cover context.
4. Given the ready availability of GPS equipment, recording and reporting spatial co-ordinates for all data presented is very valuable for comparative purposes. It allows subsequent measurements to be made in the same places and in many cases, land cover data and land cover dynamics for the sample areas to be generated from satellite imagery.
5. Disaggregation of data by landscape element and land use type. Tree cover occurs in characteristic patterns across Mesoamerican landscapes (live fences, riparian forest, secondary forest, fallows and as dispersed tree cover within pastures) and it is, therefore, valuable to present biodiversity data for each of these landscape elements separately so that the contribution of different elements can be understood and compared across landscapes.
6. For animal species within which individuals move across landscapes elements (e.g. birds, bats, mammals), simply recording their presence in a particular landscape element does not fully describe how that element contributes to the habitat requirements of the species. Recording and presenting data on activity (feeding, resting, breeding etc) increases understanding of how habitat requirements are met for whole landscapes, while marking and then tracking, resighting or recapture data permit movement for individuals across landscapes to be analysed. While intensive to measure, obtaining such data for representative species in selected taxa is required to understand how elements of the complex landscape mosaics that make up most pasture dominated landscapes, contribute to biodiversity conservation.
7. Productivity data for trees, pastures and animals as well as biodiversity measurements for most taxa, are inherently phenological and generally more so as seasonality becomes more pronounced (greater on the seasonally dry Pacific side of the isthmus than the wetter Atlantic) and where pruning is used as a management tool, as is common, for example, with live fences in pastures (Harvey et al., 2005). This makes full annual assessments more valuable than temporal snapshots. Where only one, or certain parts of the year, are sampled this should be explicitly related to sampling across the pattern of seasonal variation. Where possible, phenology of tree cover should be recorded (or derived from local knowledge) and presented together with shade measurement, and shade measurements should be made either over the entire cycle or at maximum leaf area.
8. Care is required in the interpretation of biomass or productivity data on pasture beneath and away from tree crowns. For biomass data in free grazed pasture, interpreting higher standing biomass as greater productivity is not safe, since grazing pressures may vary. For productivity measurements, root extension beyond crowns may complicate interpretation since trees may concentrate nutrients and water from a wider area close to the crown. Conversely tree litter may be blown some distance from the tree modifying nutrient inputs at considerable distances from the tree.

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