Estimating the opportunity costs of REDD+

A training manual

Version 1.3

Chapter 8. Co-benefits of water and biodiversity

Objectives

1. Explain water and biodiversity co-benefits and their importance within REDD+ mechanisms,
2. Summarize how to address co-benefits within opportunity cost analysis,

Contents

Co-benefits of water and biodiversity

What are co-benefits?

1. It is important to put REDD+ programs into perspective. Forests generate other environmental or ecosystem services which have economic value. Such services, or co-benefits, include biodiversity and water of forests, which are addressed in this chapter.

2. When co-benefits are present, REDD+ programs can affect more than reducing emissions and mitigating climate change. In forests with high levels of co-benefits, say in upper water catchments with unique biodiversity, the value of all the benefits could be significantly greater than the value of carbon alone. When this higher forest value is taken into account (a benefit to the country – not the individual), the opportunity cost of forgoing alternative land uses is lower.

3. The relationships between biodiversity, water ecosystem services, and carbon stocks are rarely simple. Within countries, just as forests have different levels of carbon, the level of biodiversity and water ecosystem services that forests provide can also be very different. Furthermore, priority areas for reducing emissions may not be the same as those for generating forest co-benefits. For example, dryer forests may have higher biodiversity and less carbon content than moist forests (Stickler, et al. 2009). In order to achieve multiple forest benefits when implementing REDD+ programs, countries will need to identify potential synergies and trade-offs of benefit provision.

4. The objective of this chapter is to present an approach to consider the effects of two of the more substantial environmental co-benefits, water and biodiversity, on the opportunity costs of REDD+.[67] It is important to note that the chapter is not a definitive analysis of water and biodiversity. Rather we discuss the potential importance of water and biodiversity services within a context of estimating opportunity costs.

What are ecosystem services?

5. Ecosystem or environmental services are the "benefits that people obtain from ecosystems." Forests, and lands in general, provide numerous beneficial ecosystem services that can be grouped into four basic types: provisioning, regulating, cultural and supporting (Table 8.1). This comprehensive framework of the Millennium Ecosystem Assessment (2006) includes services that are the focus of:

- *opportunity cost analysis:* most provisioning services,

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[67] Poverty reduction, enhanced social equity, human and indigenous rights and governance are all important REDD+ related topics that also have been categorized as co-benefits. For more on these see Brown, et al. (2008) and Meridian Institute (2009). For example, Gold Standard CDM credits emphasize carbon benefits with sustainable development benefits. For a CDM project to generate Gold Standard CDM credits, specific sustainable development criteria more stringent than UNFCCC requirements must be met. Such credits are voluntary and receive a price premium. For more information see: www.cdmgoldstandard.org/

- o *co-benefit analysis:* water provisioning and other regulating, cultural, supporting services

6. The more tangible and direct benefits come from supporting and provisioning services. Less tangible, yet still substantial benefits, are cultural services and associated social relations and livelihood security. Given that they are indirect, such benefits are often overlooked. Considering such a range of benefits helps to develop a better understanding of the many contributions the water makes to ecosystems and society.

Table 8.1. Forest ecosystem services

Ecosystem service	Examples
Provisioning	*Production of food and water (the focus of opportunity cost analysis)*
Food	Non-timber forest products such as fruits, berries, animals
Water	**Water supplies of domestic, industrial and agriculture**
Fiber	Timber, hemp, silk, rubber
Fuel	Fuel wood, charcoal
Regulating	*Control of natural processes*
Climate	Regulation of the global carbon cycle; local and regional climate regulation (albedo effects, regional rainfall etc)
Floods/drought	**Reduction of surface water runoff**
Disease	Reduced breeding area for some disease vectors and diseases transmission, such as malaria
Water	**Hydrological cycle**
Cultural	*The non-material benefits obtained from ecosystems*
Aesthetic	Scenery and landscapes
Spiritual	Spiritual significance to forests
Educational	**Genetic resources, biodiversity**
Recreational	Tourism
Supporting	*Natural processes that maintain other ecosystem services*
Nutrient cycling	Nutrient flows through atmosphere, plants and soils
Soil formation	Organic material, soil retention
Pollination	

Source: Adapted from UN-REDD, 2009.

7. Ecosystem services are interdependent. The amount of one type of ecosystem service is often related to other services, especially with forest. High priority conservation areas tend to generate multiple services with strong inter-linkages. Nevertheless, studies have shown varying degrees of interdependence amongst services. In some cases, minor or inverse relationships exist, depending on the types of services. For example, co-costs or "dis-benefits" may arise from land management practices that increase carbon density. Biodiversity can be lower within monoculture forest plantations.

8. Identifying such potential negatives are important to consider within a national REDD+ strategy. Like co-benefits, co-costs are site-specific consequences and therefore best to analyze on a case-by-case basis.

How to estimate co-benefits?

A pragmatic approach

9. To effectively address ecosystem co-benefits at a national level requires both speed and accuracy.

Tier 1: Participate and Identify

10. A first step in evaluating co-benefits of forest ecosystems is specifying the ecosystem services to be examined. Given the wide array of potential services, priorities per country will likely differ. A broad cross-section of public agencies, NGOs, academia and civil society should be involved in the identification process to ensure national ownership.

Examples: national gap analyses conducted by Parties to the CBD.[68]

Tier 2: Prioritize and Locate

11. A second step in evaluating co-benefits is to locate areas with high levels of ecosystem benefits. Such a process requires combining distinct opinions and diverse types of data. Global and regional analyses, presented below, can supplement or be adapted for national analyses.

Examples: biodiversity hotspots, catchments above urban centers.

Tier 3: Quantitatively Estimate Economic Values

12. A third step in estimating co-benefits is estimating their economic value. Such information will enable direct comparison across different ecosystem services. Nevertheless, economic values do not reflect all values of such services. Moreover, tradeoffs are often difficult to value. While economic values can guide policy decisions, other non-economic values, are likely to have influence.

Examples: Environmental service valuation and compensation schemes

Water co-benefits

13. Land use affects water and associated benefits in many ways. Table 8.2 summarizes a variety of water benefits drawn from two analytical frameworks: international river cooperation (Sadoff and Grey, 2005) and ecosystem services (Millennium Ecosystem Assessment, 2003). The ecosystem concept provides a comprehensive approach for analyzing and acting on the linkages between people and environmental services.

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[68] The CBD Program of Work on Protected Areas (PoWPA) Gap Analysis: a tool to identify potential sites for action under REDD+ http://cdn.www.cbd.int/doc/programmes/cro-cut/pa/pa-redd-2008-12-01-en.pdf

Table 8.2. Water benefits and services

Types of benefit	Water benefits / services	Type of environmental service(contribution to well-being)
Increasing benefits to water	Water quantity, quality, regulation, soil conservation, ecology/biodiversity	Supporting/Regulating
Increasing benefits from water	Hydropower, agriculture, fishing, flood-drought management, navigation, freshwater for domestic use	Provisioning
	Spiritual and religious, recreation and tourism, aesthetic, inspirational, educational, sense of place, heritage	Cultural
Reducing costs because of water	Cooperation instead of conflict, economic development, food security, political stability	Cultural (social relations and security)
Increasing benefits beyond water	Integration of regional infrastructure, markets and trade, regional stability	

Source: White, et al. 2008, adapted from Sadoff and Grey (2005) and MEA (2003).

Identify benefits

14. Another way to look at water is from a watershed perspective. Such an approach also helps associate environmental services generated from a land use, especially forests. Land-use decisions can affect the provision of watershed environmental services. Bruijnzeel (2005) provides a review of forest-water linkages. Nevertheless, disagreements are common about the extent and nature of the effects (Calder, 2005; van Noordwijk, 2005). Forest – water linkages are also often debated with many scientific results countering common beliefs.[69]

15. Land use affects watershed services by affecting:

- quantity or total water yield (streamflow)
- regularity of flow (regulation)
- quality of the water
  - lack of sediment from erosion
  - lack pollution from farm waste (e.g. manure) and fertilizer runoff.

16. The relative importance of the watershed service depends on the site-specific conditions, the type of land-use change, and on the type of water user located within the watershed. Different water users have different needs, thereby determining the type of water services required. For example, a domestic water supply system needs clean water and a regular flow. In contrast, water quality is much less of an issue for a hydroelectric power facility. Nevertheless, reducing sediment loads is important for storage reservoir.

[69] This section largely based on Porras, et al. (2008) and Pagiola, personal communication, (2010).

Quantity or total water yield

17. Forests can reduce *annual flows or quantity* of water. Experiments based on observations and theoretical reasons confirm that increased evapotranspiration from forests reduces annual flows (Calder, 1999). Forests lose more water through evaporation than other shorter vegetation, including crops. In dry conditions, the deeper roots of trees enable forests to access to water in the ground. Therefore, water losses from forests are higher in dry climates. Experiments show that evaporation from eucalyptus forests can be twice as much than from agricultural crops.

18. Forests can also increase total flows of water. In the case of cloud forests, evidence suggests that increased water yields from cloud interception (fog droplets on vegetation, sometimes called horizontal rain) offset higher rates of evapotranspiration, (Bruijnzeel, 2001)

Regularity of flow

19. The impact of forests on *water flow regulation* is also unclear. The common view that forests act as "sponges" soak up and gradually release water is widespread, although not supported by extensive evidence. In theory, forests have two opposing effects on base-level flows: (1) natural forests tend to have higher water infiltration, which enables higher soil water recharge and increased dry season flows, and (2) increased interception and transpiration during dry periods that increase soil moisture deficits and reduce dry season flows.

20. Instances of deforestation reducing seasonal water supplies tend to be site-specific and due to different factors. The type of tree species, new land uses and associated management practices affect outcomes of forest – water flow relationships. Upper catchment cloud interception can also contribute to increased dry season flows (Bruijnzeel, 2001). However, research from Costa Rica indicates that the added capture may be relatively small versus other land uses (Bruijnzeel, 2005).

21. Common management practices of non-forest land uses is a primary cause of reduced water services. For example, where deforestation is associated with high soil compaction (from roads, paths or grazing land), water runoff may rise by more than evapotranspiration declines. Similarly, exposed soils from tillage and overgrazing often cause increased runoff along with soil erosion and downstream sedimentation.

22. Forest may help *reduce flood risks* in rain events of "regular-intensity." The public perceives forests as having significant benefits in terms of reducing floods. In theory, forests may help to reduce flooding by removing a proportion of the storm rainfall and by allowing the build-up of soil moisture deficits through increased evapotranspiration and rainfall interception. Expected effects are considered to be most significant for small storms and least significant for the largest storms.

23. On the other hand, logging activities may increase floods through high impact harvesting, drainage practices, and road construction, resulting in increasing stream density and soil compaction during logging. Some early hydrological studies show few linkages between land use and storm flow. Recent evidence supports a positive relationship yet only exist in smaller catchments and during small events. Forest type and management affect the extent to which forests absorb excess water during rainy periods. In larger catchments, flooding occurs in numerous basins allowing for an averaging of flood waters. For prolonged and heavy storms, even large catchments will generate floods, but will likely occur even in forested catchments (Bruijnzeel and Bremmer, 1989).

Quality of water

24. The relationship between forest and *reduced erosion* is also not straightforward. A general belief exists that high water infiltration rates associated with natural and mixed forests will reduce surface runoff – and thus erosion. Moreover, tree roots can bind soils thereby reducing the susceptibility of soils to erosion, especially on steep slopes. Trees also help to reduce the impact of rain on soils, and thus reduce the dislodgement of soil particles. Evidence also suggests that forests are less important than other factors, such as ground cover, soil composition, climate, raindrop size, terrain and slope steepness, in determining erosion rates.

25. For any given set of conditions, however, a forested plot will typically cause less erosion. It is also important to note that water quality can also be affected by other factors unrelated to land use. Untreated effluents from urban centers or industries are a major source of contamination unrelated to forest conservation.

26. Forests *reduce sedimentation* in some circumstances. Sediment delivery depends on a range of site-specific factors, including: the size of catchments, local geology, topology, stability of river banks, and land uses and road networks (Chomitz and Kumari, 1998). Forests have two potential roles. One, forests tend to be less erosive than most alternative land uses. Degraded forests, however, can also be significant source of sediment. Two, forests located in riparian corridors can intercept sediment eroded elsewhere before it reaches waterways.[70] Although changes in land use may have significant impacts on sedimentation, comparison is needed between existing levels and before land-use change. Very few empirical studies have taken account of all relevant variables.

27. The extensive root systems of forests is commonly believed to help hold soil firmly in place and *resist landslides*. Nevertheless, this notion only hold true mostly for shallow landslides. Large landslides are not necessarily correlated to the existence of forests.

[70] This second role is un-mentioned in Porras, et al. (2008) review, but can be a very important one (Pagiola, personal communication).

28. Natural healthy ecosystems, including forests, help *maintain of aquatic habitats*. Forests positively impact the health of aquatic populations in rivers, lakes and along coasts through controlling sedimentation, nutrient loading, water temperature and water turbidity (Calder, 2005). In contrast, high sediment and nutrient loads from some agricultural land uses are particularly damaging, causing eutrophication and the development of algae blooms that starve aquatic life of oxygen and sunlight.

Quantify benefits

29. This section needs to end on a much more positive note, indicating the kinds of services that forests can generally be expected to be provide, compared to the most common alternatives of pasture and cropland. I would put reduced erosion and higher water quality at the top of that list, followed by reduced risk of flooding at the local level, and improved dry season flow with a question mark.

30. Benefits from water ecosystem services can be estimated in many different ways. These range from local participatory approaches to data intensive global analyses. The Rapid Hydrological Appraisal tool (Jeanes, et al. 2006; van Noordwijk, 2006) mixes the two. The approach brings together knowledge of land – water linkages from computer-based landscape-hydrological simulation models with stakeholder perceptions of watershed functions. Using participatory rural appraisal techniques the tool explores stakeholders' perceptions on:

- severity of watershed problems in relation to land use
- positive contributions generated from specific land-use practices
- the potential of compensation for supporting positive actions upstream.

31. The appraisal is developed over a six month period, and has five steps:

- month 1: inception and reconnaissance of stakeholders and issues;
- months 2–4: baseline (desktop) data collection of existing literature and reports;
- months 3–4: baseline (fieldwork) data collection: spatial analysis, participatory landscape analysis, surveys of local and policymaker ecological knowledge;
- months 3–5: data processing into modeling and preparation of scenarios;
- month 6: communications and refinement of the findings.

Biodiversity co-benefits

32. What happens to the opportunity costs of REDD+ when forests have a high biodiversity value? Since biodiversity of forests can generate economic benefits, the difference between the profits from forest and non-forest land uses is lower. Thus, the opportunity costs of a REDD+ program are less. Assuming that the landowners earn profits

from biodiversity, fewer funds need to be invested in order to compensate them for conserving the forest (and biodiversity).

33. Biodiversity can alleviate the need for REDD+ projects. In some high-profile biodiverse forests, the value of the forested habitat could exceed the value generated from any other land uses.[71] Tourists, for example, are often willing to pay to see mountain gorillas or jungle wildlife in national parks. If biodiversity benefits are reflected in the returns that landholders generate from a given area, such benefits are not considered co-benefits as they can be included within opportunity cost estimates. Nevertheless, land tenure arrangements can complicate such calculations as many forests are protected areas, whereby locals have rights ranging from none to limited use.

34. Should a country consider biodiversity a co-benefit to itself or not? With water services generated by avoiding deforestation, associated improvements provide benefits within the country (e.g., cleaner water, lower flood risk, etc).[72] Thus, it makes sense for a country to try to foster these benefits. In contrast, biodiversity is different. Most benefits are enjoyed outside the country. Much like the case of carbon sequestration, biodiversity is a primarily a global benefit. Therefore, a country would be unlikely to devote efforts to securing these benefits unless compensated for doing so.

35. Fortunately most countries have already prepared elaborate biodiversity conservation priority analyses, under their National Biodiversity Action Plans and other programs. Thus, REDD+ planners can utilize these existing plans by adapting associated maps to land use analyses of REDD+.

36. The range and complexity of plants and animals within a forest creates problems of biodiversity identification and quantification. Since the 1950s, debates on the measurement of biodiversity have remained at the center of substantial part of the ecological literature. This lack of consensus also has important implications for the estimating the value of biodiversity conservation. Any measure of cost-effectiveness used to guide investments in conservation must have some index or set of indices of biodiversity change (Pearce and Moran, 1994). Similarly, without accurate biodiversity co-benefit measures, REDD+ investments based on opportunity costs may not be justified. Issues of biodiversity measurement and valuation are discussed below.

Identify biodiversity: What is biodiversity?

37. *Biological diversity*, or *biodiversity*, is the variety of living plants, animals and micro-organisms on Earth. Biodiversity is used to describe a wide range of life: from genes to ecosystems. Biodiversity is different from the global stock of biological resources, a more

[71] In such cases, the opportunity costs of REDD+ could theoretically be negative.
[72] And sometimes by other countries, as with transboundary rivers.

anthropocentric term for forests, wetlands and marine habitats. Biological resources are typically known elements of biodiversity that maintain current or potential human uses.

38. Biodiversity is important for ecosystem stability and function. Ecosystem stability has two components: resistance and resilience. Resistance is the "shock-absorbing" capacity of an ecosystem, the ability to withstand environmental change. In contrast, resilience is the ability of an ecosystem to return to its previous condition or "bounce back" after it has been severely disturbed. Loss of biodiversity typically affects both ecosystem resistance and resilience.

39. Alteration or conversion of natural habitats into agricultural lands is a primary cause of rapid biodiversity loss.[73] Conversion of forests severely changes or simplifies an ecosystem. Modern agricultural practices, often monocultures of crop production, are an extreme case of simplification.

40. The potential impacts of accelerated extinction and depletion of biodiversity may be discerned sooner and later. In the long term, processes of natural selection and evolution may be affected by a diminished resource base, simply because fewer species are being born. The implications of species depletion for the integrity of many vital ecosystems are not known. The possible existence of depletion thresholds, associated system collapse, and huge impacts in related social welfare, are potentially the worst outcomes in any time horizon. More immediately, the impoverishment of biological resources in many countries might also be regarded as an antecedent to a decline in community or cultural diversity (Harmon, 1992).

Quantify biodiversity

41. Finding measures of biodiversity that can be used for policy decisions remains challenge. A number of factors cause difficulties. Determining the presence of a species or ecosystem in a specific location is not a straightforward task. Neither species or ecosystems have clear distinguishing boundaries. Although numerous species have been and continue to be identified,[74] at times the definition of a particular species or boundary between

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[73] Losses can also be caused by:

- excessive harvesting of particular species, especially of high economic value,
- consequence of invading alien species including diseases,
- impacts of pollutants,
- extinction of essential companion species (e.g., pollinators, fruit or seed dispersers),
- climate change.

These causes of loss are outside the scope of REDD.

[74] Between about 1.5 and 1.75 million species have been identified (Lecointre and Le Guyader, 2001). Scientists expect that the scientifically-described species represent only a fraction of the total number of species on Earth. Many additional species have yet to be discovered, or are known to scientists but have not been formally described. Scientists estimate that the total number of species on Earth could range from about 3.6 million up to 117.7 million, with 13 to 20 million being the range most frequently cited (Hammond, 1995; Cracraft, 2002).

species is debated and subject to revision (Gaston and Spicer, 1998). Similar difficulties challenge ecosystems. While the identification of ecosystems has improved with geographic information system technology (World Resources Institute, 2009), distinctions between ecosystems can be difficult to determine. Furthermore, ecosystems can be a moving target as climate change can have widespread effects (UNEP, 2008).

42. In sum, measurement of biodiversity is complex. Biodiversity is a multi-dimensional in scale (ranging from genes to ecosystems) and has different characteristics or attributes. Three features of biodiversity are often used to measure biodiversity: structure, composition and function, each at a different scale (Box 8.1). Structure is the pattern or physical organization of the biological components. Composition is their identity or variety. Functions refer to the ecological and evolutionary processes.

Box 8.1. Measurement approaches of biological diversity at different scales

(adapted from Putz, *et al.*, 2000)

Scale	Measurement approach		
	Structure	**Composition**	**Function**
Landscape Regional mosaics of land uses, ecosystem types	Areas of different habitat patches; inter-patch linkages; perimeter-area relations	Identity, proportions and distribution of different habitat types	Patch persistence (or turnover); inter-patch flows of species, energy and other resources
Ecosystem Interactions between members of a biotic community and environment	Vegetative biomass, soil structural properties	Bio-geochemical stocks	Processes, including bio-geochemical and hydrological cycling
Community Functional groups (e.g., guilds) and patch types occurring in the same area, and strongly interacting through biotic relationships	Vegetation and trophic* structure	Relative abundance of species and functional groups	Flows between patch types, disturbances (such as fires and floods), succession processes, species interactions
Species/population Variety of living species and their component populations at the local, regional or global scale	Population age structure or distributions of species abundance	Particular species **	Demographic processes such as death and recruitment.
Gene Variability within a species: variation in genes within a particular species, subspecies or population	Heterozygosity or genetic distances between populations	Alleles and their proportions	Gene flow, genetic drift or loss of allelic diversity.

* the position that an organism occupies in a food chain.
** can address issues of safe minimum standard.

Measurement indices

43. Species richness and species evenness are commonly used as measures of diversity (Magurran, 1988). Both indices are based on identifying and counting species. Besides the drawbacks of identification mentioned above, use of the index assumes that all species present in a plot can be counted. The total number of species, however, is too high and there is no assurance that each one has been found. To illustrate the difficulty, one cubic centimeter of soil contains so many microbes that years of analysis would be required to fully characterize them.

44. Since comprehensive biodiversity measurement is not feasible, an ongoing debate surrounds the question of which groups of organisms to sample. These subsets of biodiversity are considered a surrogate for overall biodiversity. Plants are important, as they are the primary producers in an ecosystem and animals depend on them for food, shelter, etc. Vascular plant species[75] are relatively well known (e.g., compared to fungi).

45. Certain animal groups (e.g., birds and butterflies) have been well studied and are commonly used as indicator taxa. The choice of these animals, however, has usually been due to practical considerations like their visibility (and audibility in the case of birds), and the fact that their taxonomy and biology has been relatively well studied. Care should be taken when counting the number of animal species within a plot, whichever group has been chosen. Some individuals may be temporary visitors rather than actually resident in the plot. Furthermore, land uses with different vegetation can affect the visibility (e.g., more birds can be seen an open grassland than in a densely-vegetated complex agroforestry system).

Compositional diversity

46. Species richness is the simplest measure of biodiversity. Richness (or diversity) refers to the presence or absence of species in a plot and the total numbers of species for a particular group. Box 8.2 presents analyses of species richness for three ASB sites. The Simpson Index is a measurement that accounts for the richness and the percent of each subspecies from a biodiversity sample within an area. The index assumes that the proportion of individuals in an area indicate their importance to diversity.

[75] higher plants that have lignified tissues (e.g., ferns, bushes, trees).

Box 8.2. Plant species richness in tropical forest margins

ASB scientists used a minimum standard of data collected in all sites: the number of plant species per standard plot (40 x 5 m). The results from forest and forest-derived land covers in three continents are found in Table 8.3.

Table 8.3. Plant species richness of land uses in three ASB sites

Land use	***Number of plant species within a 200 m² plot***		
	Brazil	Cameroon	Indonesia
Natural forests	63	103	111
Managed forests	-	-	100
Logged forests	66	93	108
Extensive agroforests	47	71	112
Intensive agroforests	-	63	66
Simple tree systems	25	40	30
Long fallow agriculture	36	54	43
Short fallow agriculture	26	14	39
Continuous annual crops	33	51	15
Pasture/grasslands	23	25	11
Intensive pasture	12	-	-

47. Forests typically have significantly higher levels of plant species richness. Nevertheless, disturbances to forests can increase diversity. After logging, newcomers species can cause biodiversity estimates to be greater that estimates in pristine forests (Cannon, et al., 1998).

Structural diversity

48. Species evenness is a measure of structure. Evenness is the relative abundance with which each species are represented within a specified area. The Shannon-Wiener index takes into account subspecies richness and proportion of each subspecies. The index increases either by having additional unique species, or by having a greater species evenness. The index is also called the Shannon or the Shannon-Weaver index.

49. A species richness index can account for evolutionary differences amongst species by assigning weights to species taxa. Differences in genetic composition are determined by family tree. Nevertheless, taxonomic analysis is data demanding and may not be a feasible approach for biodiversity assessments.

Functional diversity

50. Measuring only species is often considered inadequate in estimating biodiversity. Examining functions, or how plants and animals have adapted to their environment, is a

useful concept in measuring biodiversity. Plant and animal are classified according to their functions: what they do and how they do it. For example, the classification of below-ground organisms can be based on groups of animals that perform decomposition functions within an ecosystem, turning fallen leaves into other soil organic matter. Birds can be classified into functional groups (guilds) depending on their eating habits (trophic interations). Species pertain to certain 'diet guilds' depending on what they eat (e.g., fruit, nectar, insects or seeds), or into certain 'foraging guilds', depending on where they eat (e.g., in the tree canopy, understory vegetation, or on the ground). Land uses can be compared according to the percentage of species falling into each guild.

51. Plants can also be classified into functional groups. Adaptive traits (i.e. characteristics that plants have developed to exploit or cope with the conditions of a particular environment) are likely to be similar within similar ecosystems - on whichever continent. Therefore, similar functional types may conduct the same activities (and fill the same type of niche) in the forests of the Africa, Asia or Latin America. For example, across the continents, the first trees (pioneers), which grow in an open patch of land and have very large leaves, belong to different plant families. Yet, the functional types of plants are comparable across continents in different parts of the lowland tropics.

A composite approach to estimate biodiversity

52. The V-index estimates the similarity of a land use to natural forest. It is a vegetation index calculated using a set of plant-based variables that are highly correlated with land uses, plant and animal richness and soil nutrient availability (Gillison, 2000b). The index can be also used as an indicator of land use impact on biodiversity and is based on key vegetation structural, plant taxonomic and functional types (PFTs). The index is not a direct measure of biodiversity, but more an indicator to characterize habitats or sites. Nevertheless, the V-index does include measures of vegetation structure, which is important in determining biodiversity. The component measures used to calculate the V-index are:

- mean tree canopy height,
- basal area (m^2 / ha),
- total number of vascular plant species,
- total number of PFTs or functional modi
- the ratio of plant species richness to PFT richness (species/modi ratio)

53. The index is calculated using a technique called multi-dimensional scaling. Results are scaled between 0.1 and 1, with 1 being the value of natural forest. Therefore, each value of the index representing a land use indicates how much that land cover differs from the local natural forest, which serves as the reference point. An advantage of the V-index approach is that measurements are easy to make in the field (with no hi-tech equipment). Nevertheless, a computer is needed to convert the individual measurements into an index measure. Step

by step instructions regarding which data to collect, how, and how to analyze with the software are found in the VegClass manual (Gillison, 2000b).

54. The V-index was calculated for a range of forest margin land uses in Cameroon, Indonesia and Brazil. The index corresponds closely with observed impacts of land use on biodiversity, crop production and associated time since tree clearing. For example, in all sites, the V-index tends to be highest for primary forest, decreases through secondary and logged-over forests, then complex agroforestry systems, tree plantations and fallow systems and is lowest in annual agricultural crop systems, grasslands and pasture. Complex agroforestry systems based on economically-valuable tree crops have a much greater similarity to forest than monoculture plantations of the same tree crops. In Cameroon, jungle cocoa has a larger V-index value than plantation cocoa (Figure 8.1). Similarly in Indonesia, the V-index value of jungle rubber is greater than that of plantation rubber (Figure 8.2).

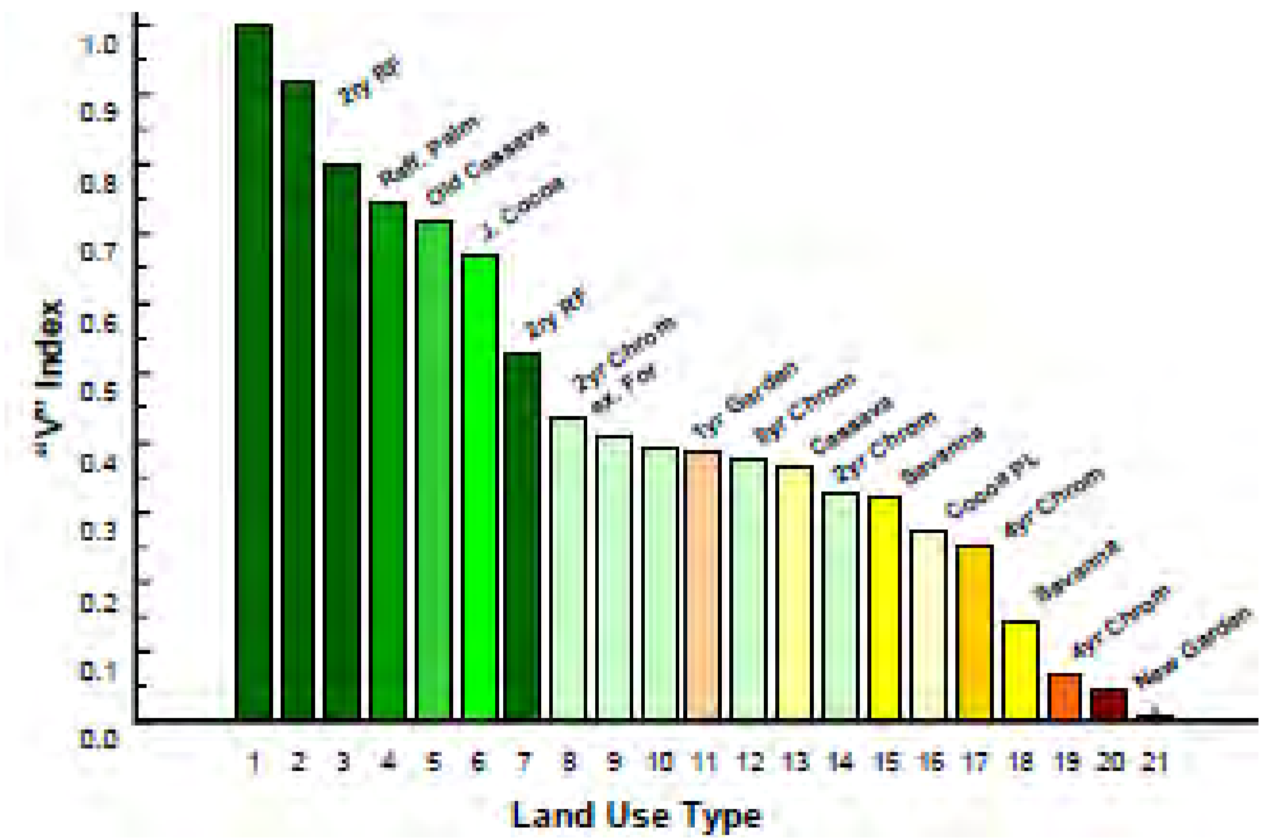

Figure 8.1. V-index values of land uses in Cameroon.

RF: Rainforest; Raff. palm: Raffia palm; J. cocoa: jungle cocoa; Chrom: *Chromolaena odorata* (fallow); Cocoa PL: cocoa plantation (monoculture).

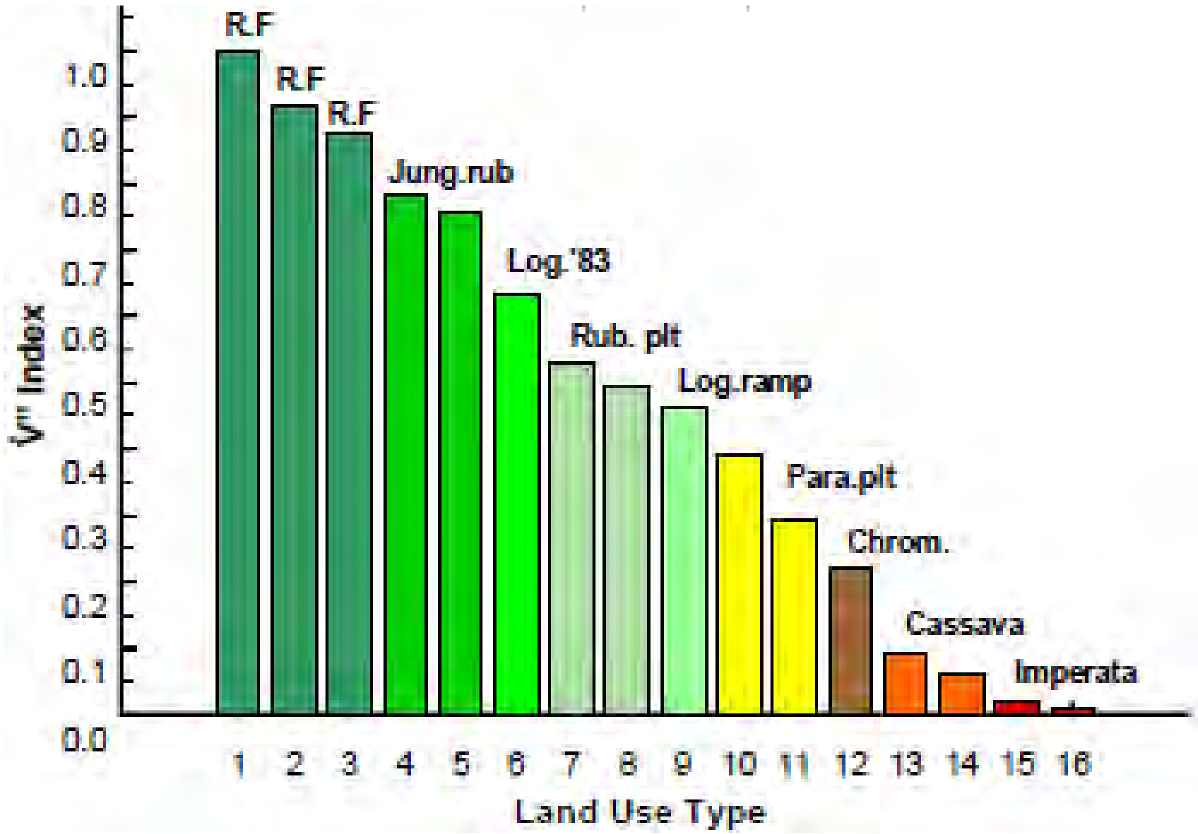

Figure 8.2. V-index values of land uses in Indonesia.

RF: Rainforest; Jung.rub: jungle rubber; Log.'83: Logged rainforest in 1983; Rub plt.: Rubber plantation; Log. ramp: Logging ramp; Para. plt: *Paraserianthes falcataria* plantation; Chrom.: *Chromolaena odorata.*

55. In summary, the V-index is a measure of the complexity of vegetation. Biodiversity is positively correlated with structural complexity and the number of ecological niches available for plants and animals.

Comparing biodiversity estimates at different scales

56. While diversity measures can be expressed per unit area, they cannot be converted easily to other units of area (Rosenzweig, 1995). In other words, estimates of biodiversity at the landscape level are not calculated by simply adding across a series of plot estimate. The same species may be found in a number of plots, and such a procedure would lead to multiple counting. As biodiversity is sampled over larger and larger areas of a particular ecosystem, the number of additional species observed will increase, but at a decreasing rate (Figure 8.3). Eventually the curve levels off, meaning that even though the area may increase, any new species will not be found.

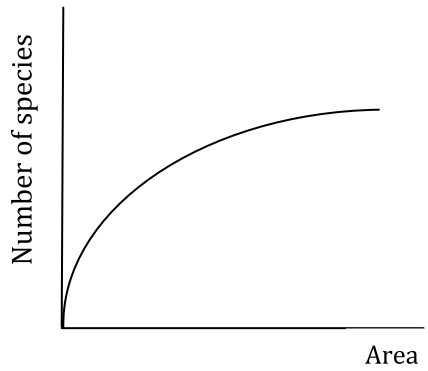

Figure 8.3. A species-area curve

Box 8.3. A cautionary note with species-area curves

Scaling relations (the shape of the species-area curve) may differ between types of vegetation (Figure 8.4), or between types of species. This may be due to fundamental differences in the ecology of the species or vegetation type. Therefore, comparison of species richness per plot is valid only for plots of the same size in two different land uses.

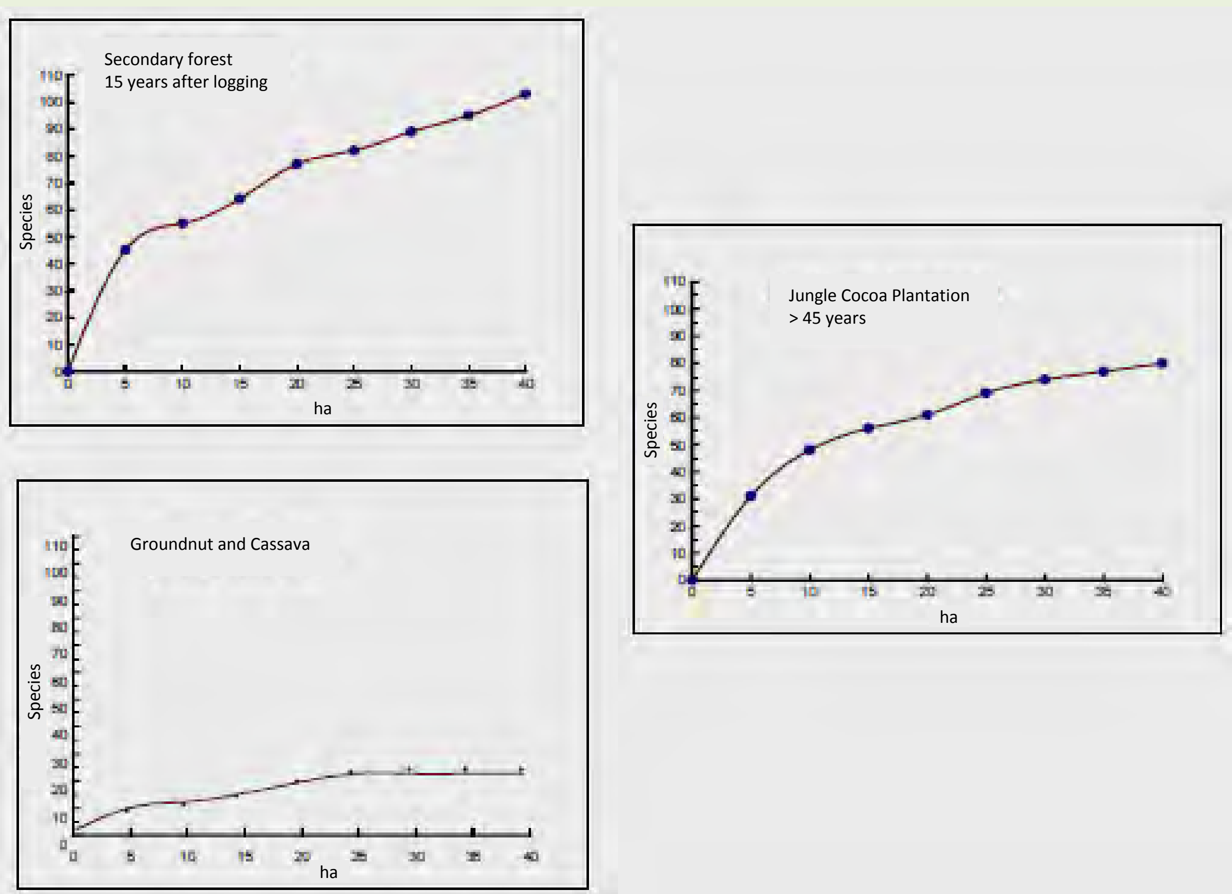

Figure 8.4. Species area curves for three land uses in Cameroon

Source: Gillison (2000a)

57. Another way to examine scalar relationships of biodiversity is to associate three types of diversity (Figure 8.5).

- Alpha diversity – is species richness within a particular area, community or ecosystem, measured by counting the number of taxa within the ecosystem (typically species).
- Beta diversity – is species diversity across ecosystems, comparing the number of taxa that are unique to each of the ecosystems.
- Gamma diversity – is species richness of different ecosystems within a region.

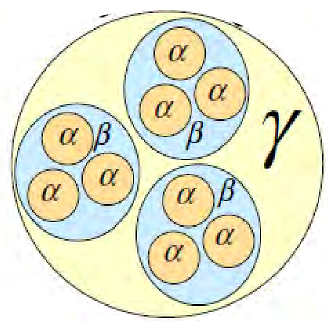

Figure 8.5. Biodiversity at different scales

58. For analysis of tropical forest margins, ASB contrasted the biodiversity of land uses. To obtain results comparable across the sites, standard protocols were used. The methodology for choosing plots can be found in Gillison (2000b). The studies were complemented by a detailed baseline study in Indonesia, which collected detailed information on vegetation, birds, insects, soil animals and canopy dwelling species (Gillison, 2000a).

Biological resources and conservation priorities

59. Given the data requirements and difficulty of measuring biodiversity, biological resources (e.g., species and ecosystems) are often used as a surrogate in the development of conservation priorities and strategies. The species-area relationship in regions of high species richness is one rapid approach to identifying conservation priorities (Brooks, et al. 2006). When such hotspot areas are under threat of land conversion, priorities can become urgent. Nevertheless, the cost of conservation efforts may be high and chances of success low, thereby further confounding biodiversity conservation challenges.

60. Gap analysis is another method to identify biodiversity (i.e., species, ecosystems and ecological processes) that are inadequately conserved within a protected area network or

through other long-term conservation measures. Although the number and size of protected areas continue to grow, a large number of species, ecosystems and ecological processes are not adequately protected. Gaps come in three basic forms:

- Representation gaps: a particular species or ecosystem does not exist within a protected area, or examples of the species/ecosystem insufficient to ensure long-term protection.
- Ecological gaps: although the species/ecosystem is represented in an area, the occurrence is either of inadequate ecological condition, or the protected area(s) fail to address the changes or specific conditions necessary for the long-term species survival or ecosystem functioning.
- Management gaps: protected areas exist but management (objectives, governance, or effectiveness) do not provide adequate security for particular species or ecosystems.

61. Gap analysis is a process that starts by setting conservation targets. Next, biodiversity distribution and status are evaluated and compared with the distribution and status of protected areas. The CBD Program of Work on Protected Areas (PoWPA) gap analysis can provide mapping data and tools for REDD. For more on gap analysis and recent research results see Dudley and Parish (2006), Langhammer, et al. (2007) and IUCN publications.

Value biodiversity

62. Despite the importance of biodiversity, economic valuations are often complex, expensive and likely imprecise. To address these shortcomings, non-economic methods exist that help to examine public concern for biodiversity. Insights gained from public participation can complement benefit-cost approaches for policy decisions. **Appendix E** includes details on estimating the value of bio-diversity also the references below contain numerous sources.

Co-benefits and opportunity costs

63. Benefits of forests can be divided into three categories:

- on-site benefits (e.g., fuelwood, timber, non-timber forest products, tourism)
- off-site benefits
    - within-country (e.g., protection of water services).
    - outside-country (e.g., carbon sequestration and biodiversity habitat).

64. Within REDD+ discussions, off-site within-country benefits are typically termed: co-benefits of conserving, improving or establishing forests.

65. Here we present two sample "Tier 2" studies. Pagiola, et al. (2006) identify areas within the highlands of Guatemala that are important for water and biodiversity services. Such information can be used in conjunction with opportunity cost estimates to determine whether particular areas should be prioritized within a REDD+ program (Box 8.4). The second example of co-benefits maps comes from Tanzania (Box 8.5).

Box 8.4. A national analysis of water and biodiversity benefits

Spatial analysis of water and biodiversity can help identify priority conservations. For example, Pagiola et al. (2007) developed maps of water supply and biodiversity conservation priority areas in Guatemala. Maps contain a simple but useful amount of quantification, and could be made more complex if and when data become available. Figure 8.6 shows a relationship between municipal water supply systems and associated supply systems. Darker red areas highlight areas that serve more households per area of catchment. This calculation can serve as a potential indicator of water co-benefit.

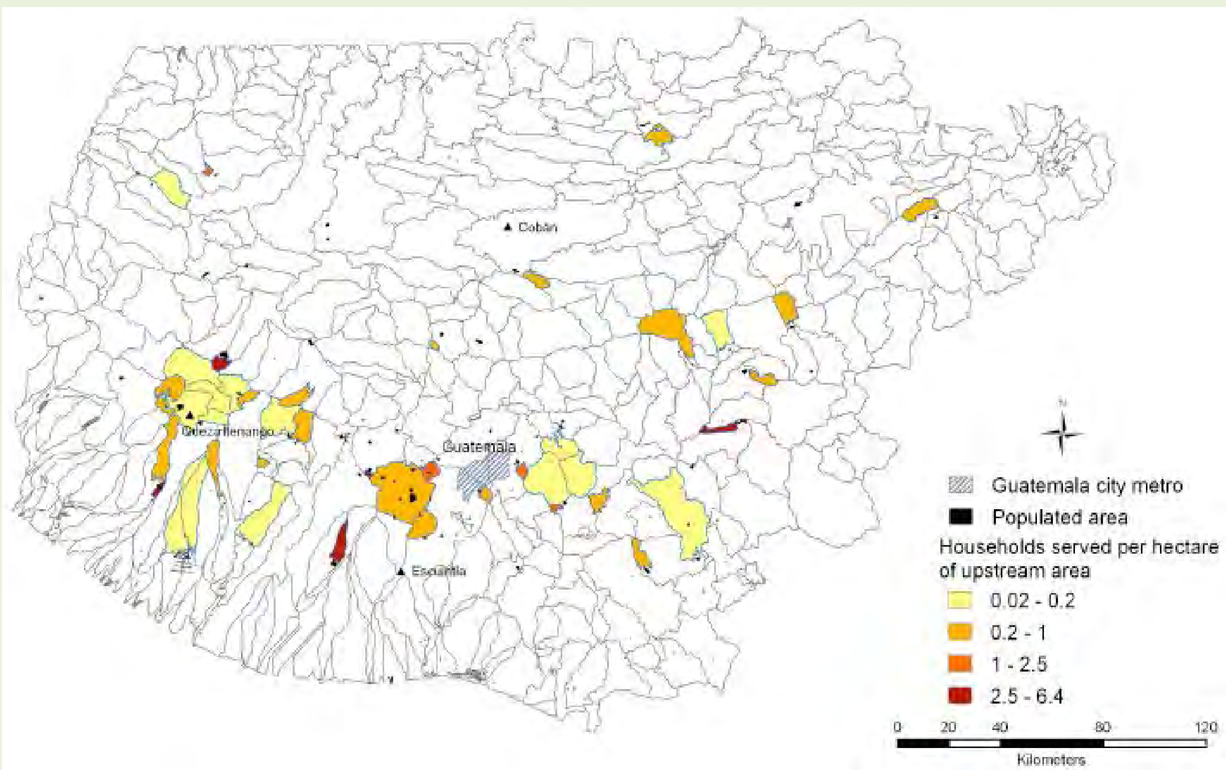

Figure 8.6. Municipal water systems and supply areas, Guatemala.

Source: Pagiola, et al. 2007.

Box 8.5. National analysis of multiple benefits: An example from UN-REDD

An effective way to identify and document co-benefits is through maps. One example of a recent effort is from UN-REDD+ Program at the UNEP World Conservation Monitoring Centre (WCMC) and the Tanzania Ministry of Natural Resources and Tourism. A national-scale analyses of co-benefits and other factors was conducted, including population density, honey-beeswax-gum production, and mammal and amphibian species richness (Figure 8.7). In addition, a revised combined soil and biomass carbon map for Tanzania was produced (UN-REDD+ Program, 2009).

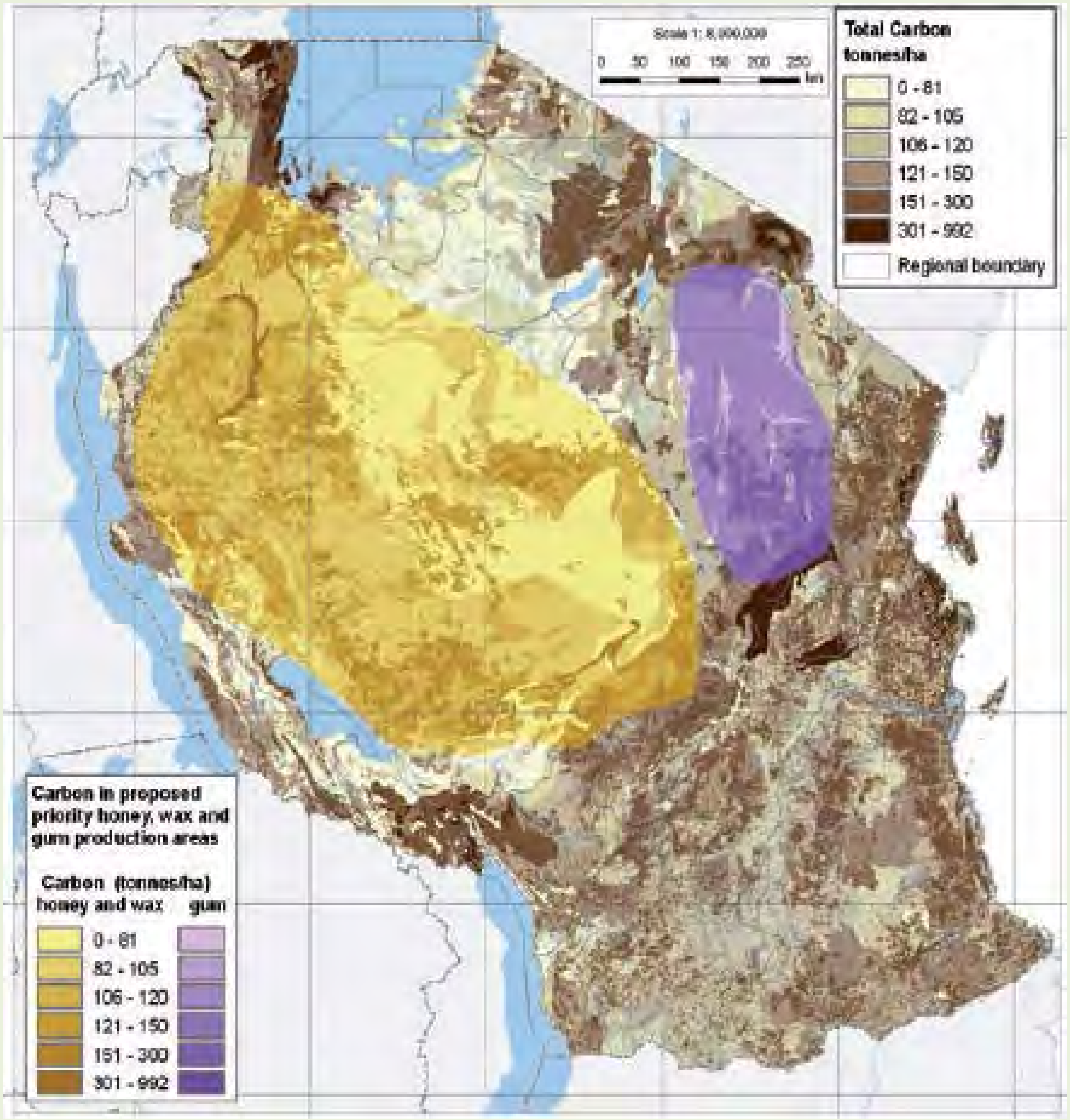

Figure 8.7. A combined NTFP priority areas and soil-biomass carbon map of Tanzania

Source: Miles, et al. 2009.

66. Naidoo et al. (2008) reviewed theory, data, and analyses needed to produce ecosystem services maps. Data availability allowed the quantification of imperfect global proxies for four ecosystem services: carbon sequestration,[76] carbon storage,[77] grassland production of livestock and water provision. Using this incomplete set as an illustration, ecosystem service maps were compared with the global distributions of conventional targets for biodiversity conservation.

67. Preliminary results show that regions selected to maximize biodiversity provide no more ecosystem services than regions chosen randomly. Furthermore, spatial concordance varies widely amongst different services, and between ecosystem services and established conservation priorities. Nevertheless, "win–win" areas of ecosystem services and biodiversity can be identified, both among eco-regions and finer scales. An ambitious interdisciplinary research effort is needed to fully assess synergies and trade-offs in conserving biodiversity and ecosystem services. Comparisons of these attributes of land use changes can reveal tradeoffs and synergies useful for understanding the potential role of REDD+ policy to foster desired outcomes.

An example of co-benefit analysis

68. Although the value of co-benefits is very difficult to estimate and even more challenging to convert into per hectare values, opportunity cost analysis can guide where:

a. quantification and perhaps valuation efforts are priority,
b. the identification of land uses to include in a REDD+ program.

69. Figure 8.8 contrasts five emission abatement situations with different abatement costs and water co-benefits. For the purposes of illustration, these situations refer to a change from forest to agricultural land use with co-benefits from downstream water quality and availability. In order to directly compare both carbon and water benefits, the same unit of analysis must be used. This example converts the typical $/ha estimate of water co-benefits to a $/tC02e measure (requires dividing the water co-benefits by the associated tCO2e of the land use). Water co-benefits can be considered REDD+ cost reductions, as represented by lighter green area.

70. Options A, B, and C have REDD+ costs less than the price of carbon (Pc). In contrast, option E has REDD+ costs higher than Pc. Only options A, B, D and E have water co-benefits. Even without the water co-benefits Options A, B and C would be priorities for REDD+ program inclusion given their low REDD+ costs. With the large water co-benefits, options B and D would be more of a priority that option A.

[76] Net annual rate of atmospheric carbon added to existing biomass carbon pools.
[77] Amount of carbon stored in vegetation both aboveground and belowground.

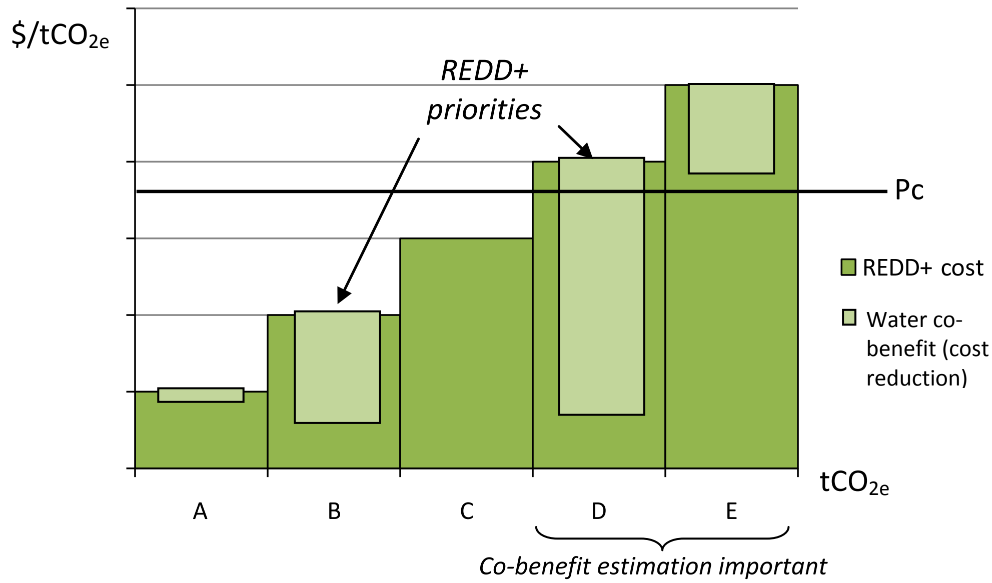

Figure 8.8. Identifying priority co-benefit analyses
Adapted from: Pagiola, 2010 personal communication.

71. Options D and E have higher REDD+ costs than the carbon price and would normally not be included in a REDD+ program. With consideration of water co-benefits, however, the option D would viable. Estimating benefits is more important for the case where the REDD+ costs exceed the price of carbon. In cases where the carbon costs are less than carbon price (Options A, B, C, D), estimation of co-benefits is less of a priority.

72. With respect to biodiversity co-benefits, an analysis would be similar – except that benefits can rarely be realized by a country. Protecting high biodiversity areas typically generate benefits outside the country (especially if tourism is not linked to biodiversity). Within Figure 8.8, avoiding deforestation in Area E based on carbon payments and water co-benefits may not be in the best interest of the country. The alternative land use poses greater benefits. Nevertheless, the country could try to attract a biodiversity-oriented donor to complement the carbon payments in order to make conservation viable.

Conclusion

73. The value of co-benefits can be substantial and greatly affect the opportunity cost estimates of REDD+ projects. Whether to or how to recognize water and biodiversity benefits within REDD+ policies is still being discussed (Ebeling and Fehse 2009; Pagiola and Bosquet, 2009). Though a REDD+ mechanism offers opportunities to achieve both carbon and other co-benefits, the limitations of a REDD+ mechanism to act as a panacea for biodiversity loss or water problems needs to be challenged. Overemphasis on non-climate change objectives within a REDD+ mechanism comes with a risk of raising transaction costs, potentially reducing the ability to conserve forests.

74. Specific suggestions for policy-makers include the following :

- *Biodiversity* [78]
    - Develop a national information base on national biodiversity to increase the likelihood of achieving and maximizing a range of biodiversity co-benefits in REDD. Biodiversity-targeted funding can then have better understanding of biodiversity and aim to complement REDD+ financing, such as focusing in areas with high biodiversity and low carbon benefits.
    - Link on-going REDD+ demonstration activities with biodiversity performance assessments of monitoring, reporting and verification. This will enable the analysis, comparison, and evaluation of different approaches and methods used to promote biodiversity co-benefits in a REDD+ context. Lessons learned during the implementation of these REDD+ demonstration activities can ultimately feed into the international and national level policy-making processes.
    - Establish a technical working group on REDD+ biodiversity co-benefits to develop best-practice guidelines and principles, including indicators for biodiversity. Such a group could also help guide the policy decisions and implementation REDD+ activities at the national, regional and/or local levels.
- *Water*
    - Establish an national information base (e.g., inventories, maps) of water resources to increase the likelihood of achieving and maximizing water co-benefits in REDD. Water-targeted funding can then work within a REDD+ context, in order to focusing on areas of important water services (e.g., upper catchments).
    - Support and review efforts in modeling water ecosystem services and link government decisions with national REDD+ policy development and implementation. The clarification of diverse water services (e.g., flow regulation, water quality, etc.) will help policymakers prioritize government investments and actions.
    - Establish a technical working group on REDD+ water co-benefits to develop best-practice guidelines and principles, including indicators for water services. Such a group could also help guide the policy decisions and implementation REDD+ activities at the national, regional and/or local levels.

[78] Adapted from Karousakis (2009).

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