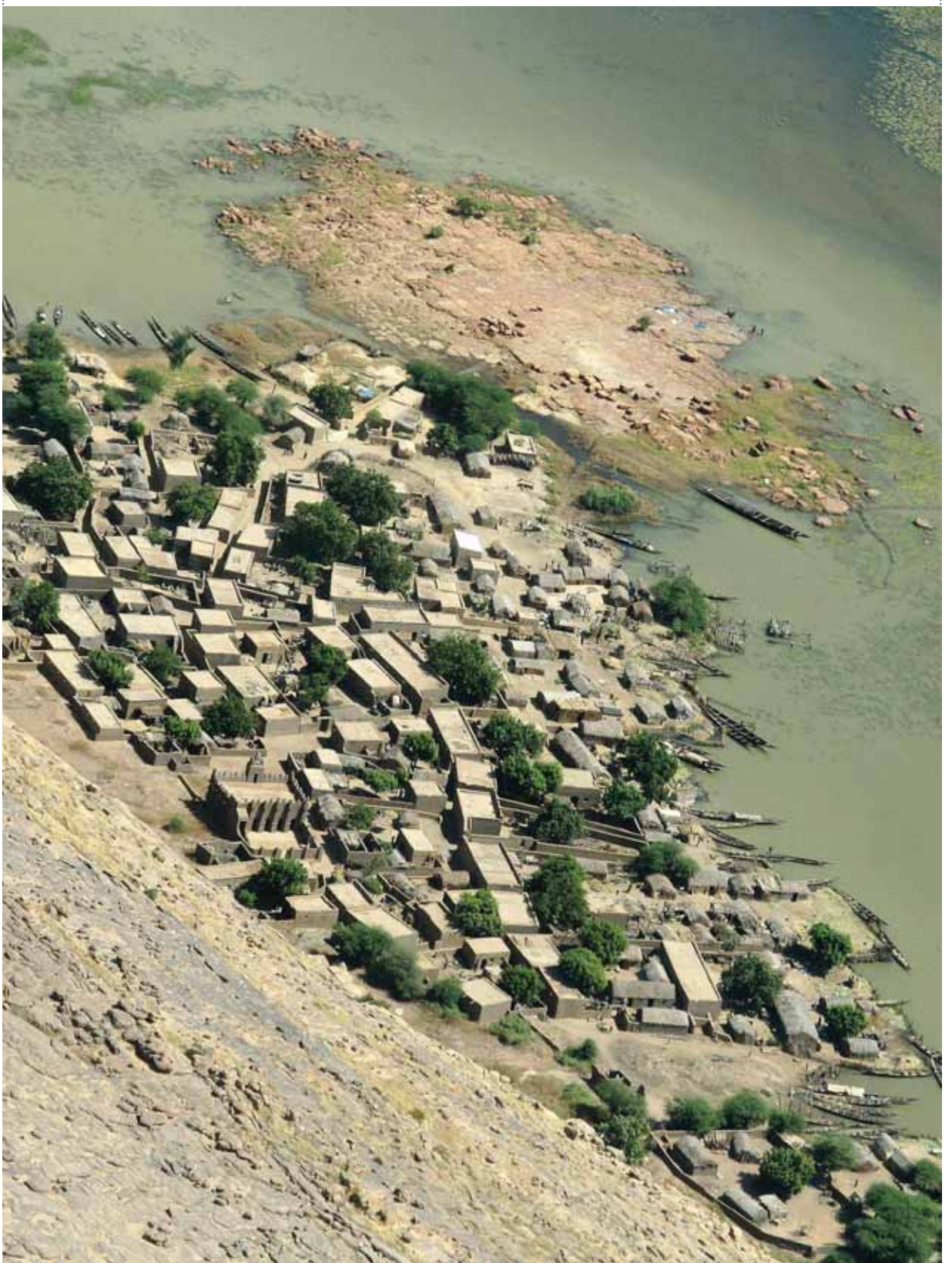
Part 1: Towards Assessing Trees Outside Forests: Why, what and how?

Content

1. Background and Rationale



1.1. Trees and Forests: Two facets of the same resource

In human-influenced landscapes where ecological conditions are favourable to tree growth, trees can be found in a wide range of situations and spatial patterns.

This first section builds on a selection of high resolution satellite images freely accessible on the Internet via Google Earth, to help showcase some of the different tree-forest arrangements in relation to their environmental and socio-economic context, along with the various goods and services they provide.

Trees and forest on the same farm

In image 1 above (Normandie, France, 240 m asl), trees on the right side form a forest, a large, compact and dense block of trees. In the agricultural mosaic that spreads on the left side, trees are also present, although at a much lower density than in the forest. Lines of trees have been planted along the road at the far left, and on the borders of cropfields and pastures. Apple trees have been planted on grazing land in the two farms on the left. Trees are present in the private gardens of every farm in the image. Two small woodlots with poplar trees are adjacent to the forest.

In a rural environment like the one depicted above, each farmer manages his/her homegarden and agricultural land. In France about 75 percent of the forest is private, so farmers may also own and manage a piece of forest land. The above example shows trees in four major treed land uses: forest, hedges bordering cropfields and pastures, fruit orchards, and homegardens. Trees in such a mosaic are managed differently according to each land-use. Trees in the forest are managed primarily to produce high value timber and fuelwood, for home consumption or for income. Tree hedges along fields' borders are spatial markers of ownership but are also often managed as living fences and for fuelwood. Apple trees are managed for fruit but also provide shade for cattle. In homegardens, people manage trees for fruit, shade, and aesthetic values.

Trees thus provide a variety of products and services, some of which are independent of land use while others are land-use specific.

In the example above, the forest does not provide apple fruits, but it does ensure certain biodiversity functions, such as niches for some rare herb and bird species, functions that cannot be provided by any other land use. Moreover, although some products and services provided by trees are the same in every land use, their amount or intensity generally depends on the land use. The forest in image 1 provides much more timber and fuelwood per unit-area than the tree hedges.

Trees on farm and restricted access forest

In many rural areas forest is present but inaccessible to farmers, for example along borders of forest concessions, forest reserves or national parks. Therefore farmers can only rely on trees they grow on their agricultural land and in their homegardens.

In image 2 above (Kericho, Kenya, 2040 m asl), the dense and compact tree cover on the left is protected forest. Outside the forest, trees appear in homegardens, isolated or in small groups in some fields, as hedges, in a narrow discontinuous line along the small river, and also along the road. As in the first example, trees accessible to farmers provide a variety of products and services such as ownership boundaries, fencing, shade, fertility maintenance, and erosion control.

In images 1 and 2, trees in forest and trees outside forests under their various spatial patterns provide complementary products and services. In image 1 they are complementary at both farm and landscape level but only at the landscape level in the second image. Trees in forest and trees outside forests may be considered as two facets of the same resource.

No forest but trees on farms: areas with potentially dense tree cover

In many rural areas, forest blocks have disappeared, but trees often are still present in the landscape, and sometimes in large amounts. This is the case in many countries where forest was converted to other land uses with increasing density of human population. The lowlands of Sumatra, Indonesia, were covered by dense tropical rain forest one century ago, but are today a mosaic of agricultural land with lots of trees planted by farmers.

In image 3 below (Tanjung Moravia, North Sumatra, 40 m asl), the left half is the dense tree cover of an oil palm monoculture plantation. Paddy fields on the right are almost devoid of trees. Trees in homegardens and multistrata agroforestry systems form a dense cover between the paddy fields and the oil-palm plantation. This is typical of many areas of the Sumatran lowlands, where trees are found in huge numbers, in monoculture plantations (oil palm, rubber, Acacia), homegardens, and multistrata agroforestry systems (Tomich et al., 2002; Feintrenie et al., 2010; Broich et al, 2011). The trees that replaced the forest provide similar environmental services (e.g. soil protection, water regulation, carbon sequestration) but in lower amounts and with one important exception –biodiversity conservation. Forest conversion led to the disappearance of most forest animal and plant species and loss of diversity (Michon et al., 2007; Fitzherbert et al., 2008; Sodhi et al, 2010; Schroth and McNeely, 2011).

Another land use – agroforest – that replaced the initial forest is worth mentioning, although its area is currently declining in Sumatra (Kusters et al. 2008; Ekadinata and Vincent, 2011). In image 4 below (Muara Bulian, Jambi Province, 35 m asl), apart from the homegardens near houses, the entire landscape is occupied by rubber agroforest plots at various stages of development, with the clearings representing the initial phase of a new cycle expected to lead to the mature and productive agroforest that currently occupies most of the area.

The diverse tree species assemblage established by farmers in agroforests (such as rubber agroforests or damar agroforests) ensures vital economic services. In addition, contrary to the other treed land uses, agroforests provide habitat for many forest animal and plant species, ensuring significant biodiversity conservation (Michon and de Foresta, 1992; Beukema et al., 2007; Bhagwat et al., 2008; Idol et al., 2011).

No forest but trees on farms: areas with limiting tree growth conditions

Trees may also occur in agro-ecosystems with limiting growth conditions (dry lands, cold mountains, highest latitudes), resulting in low tree densities in the landscape. In drylands, trees are always present where environmental conditions allow, and they offer vital economic, environmental and sometimes cultural and religious functions (Boffa, 1999; Faye et al., 2011). In image 5 below (Syoro, Burkina-Faso, 330 m asl), trees either isolated or in small groups are everywhere in this agricultural and settlement landscape. This is representative of the agroforestry parklands that spread all over the Sahelian zone. Often labelled as forest by foresters, these agroforestry parklands are the result of a long intergenerational history of management by local people who selected and favoured the various tree species most adapted to their needs (Boffa, 1999).

Trees in cities

Trees are also commonly found in villages, towns and large cities. According to the United Nations Population Fund (UNFPA), for the first time in history more than half the world population is living in towns and cities. The urban population will likely grow to 4.9 billion by 2030, while the world's rural population is expected to decrease by 28 million by then (UNFPA, 2007). As cities grow they include in their spatial expansion an increasing number of rural areas, sometimes endowed with forests (Yuan Wang et al., 2009; Lugo, 2010; Nowak et al., 2010; Weiqi Zhou et al., 2011). When forest areas become city parks, they lose their production function but keep most of their environmental services function and gain a "greening" function, much valued in areas dominated by buildings and houses (e.g. Konijnendijk et al., 2005). Even cities that do not include forest areas are never treeless (except maybe in the most extreme dry climatic conditions), with trees planted and managed for aesthetic and environmental values: in private gardens, along streets and in public parks. Trees provide vital services to city dwellers such as moderation of microclimate, pollution and flooding, and a "green" environment conducive to good health (e.g. Bowler et al., 2010). On urban peripheries with fewer constraints on space, people also manage trees in private gardens for fruit production (Eriksen-Hamel and Danso, 2010; Lovell, 2010).

Image 6 below (Mexico-city, Mexico, 2230 m asl) shows that even in megacities , trees are present, often in large numbers.

The satellite images presented in this section show that:

- ✓ Trees occur mainly in three land uses: forest and natural woodlands, agricultural lands and urban lands,
- ✓ Trees grow under three main patterns: compact blocks, scattered in the landscape and in linear formations.

Whether trees are part of a forest formation or appear under any of the many spatial patterns found outside forests in rural and urban areas, trees offer numerous environmental, social, cultural, aesthetic, and economic services and vital products - fruit, oil, gum, resin, fodder, medicine, timber, fuelwood - essential for the livelihood of billions of people all over the globe.

1.2. Forest and Non-Forests: A history of dividing the resource

In most countries, a distinction between "Forest" and "Non-Forest" (other land uses) is made. This distinction most often results from a long history, involving production, management, and environmental considerations, but also involving resource control considerations (Ribot, 1999, 2001; Barton, 2002; Williams, 2003; Fay & Michon, 2005; Peluso & Vandergeest, 2011).

This distinction, translated into the legal, policy and institutional framework, generally led to the formalization of various criteria for classifying a given area as forest. These criteria are extremely diverse and their combinations vary from one country to another (Lund, 2002). The combinations usually involve land use or/and land-cover criteria, but may also involve ownership criteria.

One major impact of the line drawn between forest and non forest has been a corresponding divide between institutions dealing with forest resources and institutions dealing with other land uses, even when these land uses include trees (Fay & Michon 2005). A second major impact has been that interests regarding trees and tree products and services have concentrated on the forest side of the divide, with forestry institutions in charge (Van Noordwijk et al 2008). On the other side of the divide, institutions in charge of agriculture, rural development and rural planning historically prioritized crops and livestock and considered trees most often as a minor component, even where trees were vital for the livelihoods of many.

Forestry institutions over time developed ever more sophisticated methods to inventory, assess and monitor trees in forest and the products and services they provide (Tomppo et al., 2010). On the other side of the divide, agriculture institutions developed methods to inventory, assess and monitor crops and livestock, ignoring trees on farmland except when they belong to the quite restricted "tree-crops" category. Many of the maps realized by forestry on one part and by agriculture or rural planning institutions on the other part appear as a caricature of the divide: forests are reported under a number of categories and with a luxury of details in forestry maps, while other land uses appear as "terra incognita" and are often merged into one or a few "black boxes" called "unused land", "agriculture land" or "other land" (Harley, 1988; Vandergeest, 1996; Walker & Peters, 2001;). This is the reverse for maps prepared by agriculture or rural planning agencies, with many different agricultural land-use categories that generally superbly ignore the tree component except for "tree crops", and only one category for forest.

The FAO-FRA land classification system is no exception, with all land uses other than Forest and Other Wooded Land being encompassed in the "Other Land" category (FAO 2010a,2010b).

Only relatively recently has appeared the need to bridge that historical divide, need fueled inter alia by the development of agroforestry with its explicit acknowledgement of the importance of trees on farm and its difficulties in finding its niche because of the institutional divide (Nair,1998; Montambault & Alavalapathi, 2005; Valdivia et al. 2012). Even more recently, the pressure for bridging the divide soared because of rising global issues such as climate change mitigation with the appreciation of the role of trees – inside and outside forests- in carbon sequestration, and poverty alleviation with the acknowledgement of the livelihood importance of tree products and services (Nair, 2011; Schroth et al., 2011; Stringer et al., 2012).

The FAO-FRA programme acknowledged this need to bridge the divide and to better take trees that are not located in forests into account. In particular, its land classification system has evolved since 2005 with the introduction of "Other Land with Tree Cover", a new subcategory of "Other Land" that includes part of the trees outside forests. The present report is another effort in this direction.

1.3. Reporting for managing, planning and monitoring – Why, Who and How?

The needs for planning, monitoring and evaluating at various levels

Why assess trees and forests at the farm level?

In a farm composed of various land-use units, the farmer consciously or unconsciously integrates in day-to-day management the assessment and monitoring of the state and health of the various farm components, including the trees. This monitoring is crucial to the good functioning of the farm in the short run, allowing the farmer to efficiently plan its activities, for instance the harvesting of a crop, the pruning of trees, or the cutting of trees for fuelwood or timber. Assessing trees and forest resources on a farm is also important for planning and managing the evolution of production in the long run, in accordance with the expected changes in the needs and constraints of the farmer and his/her family. For instance, the farmer could plan to convert one field into a small woodlot with high value timber that would involve less labor and build a patrimony for her/his children.

Why assess trees and forests at sub-national and national level?

In a district, a province or a country, policy and decision-makers at each level need to know the state of the resources present in their constituency in order to plan their management on a sound basis. They need to know the location, amount and production of each resource, and their contribution to the economy and livelihoods of local communities, and their economic, social, cultural and environmental values. They also need to know the past changes in these different parameters, in order to make informed hypotheses regarding expected

trends. With growing appreciation of information and openness in society, policy makers also increasingly need to show voters that their interests are taken into account, that detailed assessments are made, and that results of these assessments are effectively communicated to the public.
In most countries, at sub-national and national levels, forests have a special status that distinguishes them from all other land uses, with the institutional consequences mentioned above. Forestry services assess and monitor the tree resource in forests, with integration of data up to the national level. Agricultural services assess trees on agricultural land (often limiting their assessment to monoculture "tree-crops"). Here also, reports are integrated up to the national level. Trees in cities are generally assessed by municipal services, but in general reports are not integrated up to the national level.

On the basis of these reports prepared by the various sectors, most often with little connection between sectors, sub-national and national governments may take decisions that impact resource management, for example introducing payments for environmental services (PES) to farmers who grow trees in contour lines for controlling erosion and run-off in mountainous areas. They may also take planning decisions such as launching a woodlot development program with the aim of being self sufficient in timber and fiber products in 30 years.

Assessing and monitoring trees and forests at these policy levels uses methods and financial resources that are very different from those used at the individual farm level. The main purposes are however the same in both cases: management and planning.

Reporting to international organizations and international conventions emerged over the last half century as another important reason for assessing and monitoring tree and forest resources at the national level.

Why assess trees and forests at supra national and global level?

Countries do not live in isolation. Adjacent countries often share the same climate and environmental conditions and therefore often share similar problems regarding the management of their tree and forest resources. For instance, countries in the Sahel region share some of the same environmental constraints linked to a hot and dry climate with irregular annual rainfall, which may easily lead to the degradation of fragile socio-agro-ecosystems developed by local communities.

The sustainability of local socio-agro-ecosystems is almost everywhere dependent on the presence of trees and forests and of their wise management. But this dependence is nowhere more intense than in the Sahel where trees can make precious underground water resources accessible to crops (Bayala et al., 2008; Asbjornsen et al., 2011), the starting point for food production and human livelihood. Because they share not only the same environmental constraints and problems, but also the same kind of socio-agro-ecosystems adaptations where trees have a crucial role, it is clear that to understand and manage tree and forest resources, countries in the Sahel would benefit from a regional assessment and/or integration of their national assessments regarding these resources. Based on such a regional assessment, countries could compare their national policies and identify policies that re-enforce the sustainability of socio-agro-ecosystems.

While such regional assessments are still utopian for most regions, almost all countries do join together to carry out regional and global assessments under the auspices of the United Nations. In doing so, they fulfill their obligations as signatories of one or more of the three international conventions that relate directly to forests, trees and other biological resources: the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention on Biological Diversity (CBD), and the United Nations Convention to Combat Desertification (UNCCD). The three conventions underpin the Rio Declaration on Environment and Development, which laid down principles for responsible resource utilization and conservation, and which underlined International cooperation as essential for efficiency and equitable global economy (Keating, 1993).

As demonstrated below, management of forests and trees is important for the implementation of all three conventions.

UNFCCC

The forestry sector (including deforestation and associated land-use change) contributed 17.4 percent of the world's total annual greenhouse gas emissions in 2004 (IPCC, 2007). Natural forests are declining world-wide and especially in the tropics through conversion to agriculture. Recent research has shown that tree cultivation is expanding rapidly on

farms and that almost 50 percent of the agricultural land worldwide has at least 10 percent tree cover (Zomer et al., 2009). These trees on agricultural land may not be able to provide all the environmental goods and services that could come from well managed forests. However, they do provide a measure of carbon sequestration, and can inter alia, increase the capacity for farmers not only to adapt to the effects of climate change, but also to contribute to their mitigation. UNFCCC's COP 16 in Cancun Mexico (2010) came up with interesting developments on REDD+ where SBSTA (Subsidiary Body for Scientific and Technological Advice) was asked to develop a work programme on drivers of deforestation, along with MRV (measurement, reporting and verification) protocols (UNFCCC, 2011). One important driver of deforestation is agriculture. Considering that there are global efforts to intensify tree cultivation on agricultural land, the impact of such efforts will have to be included in the MRV protocols. This creates the need to have robust methodology for inventorying and monitoring trees in agricultural and other landscapes. Baseline data are needed to help establish the current status and thereafter periodic monitoring of tree resources would reveal landscape level changes in stocking, leakages, etc.

CBD

Under the Convention on Biological Diversity (CBD), COP 10 in Nagoya Japan (October 2010) adopted the Aichi Target where, by 2020, the world would at least halve the rate of loss of natural habitats, (including forests), protect 17 percent of terrestrial and inland water areas and 10 percent of marine and coastal areas; and restore at least 15 percent of degraded areas (Djoghlaf, 2010). Countries are translating this overarching framework into national strategies and action plans. The latter include the planting of vegetation in different landscapes. Actions to support the Aichi Target are expected largely at sub-national and local levels; this requires measuring and monitoring efforts.

UNCCD

The United Nations Convention to Combat Desertification (UNCCD) includes measures to prevent and /or reduce land degradation, rehabilitate partly degraded land and reclaim desertification areas. Large areas of Africa, Asia, Australasia and the Americas are identified as highly vulnerable to desertification. Among other measures, one strategy is the planting of trees and shrubs in a variety of formations to conserve soil and water and restore ecological functions. Many countries promote the use of leguminous plants to restore soil fertility.

The Great Green Wall for Sahel and Sahara Initiative (GGWSSI) was conceptualized as a green belt of trees and bushes 15 km wide, and up to 8 000 km long, stretching across Africa from Djibouti to Senegal (OSS & CEN-SAD 2008). Eleven Sahelian countries (comprising Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Nigeria, Senegal and the Sudan) and their international partners saw this as way to mitigate desertification along the southern border of the Sahara desert. In practical terms, this 'wall' is planned to be built out of multifaceted international economic and environmental programmes.

Similar initiatives are taking place in different parts of the world to implement UNCCD programmes and other greening efforts. It is important to be able to monitor the resources generated by these initiatives and to provide guidance on how best to manage them.

Despite the obvious linkages among the three conventions (UNFCCC, UNCBD and UNCCD), their organizational structures and mechanisms for implementation are not closely coordinated. Two interventions that are common to all three conventions are 1) supporting the regeneration of natural vegetation and 2) planting trees in various landscapes. National assessment and monitoring of the tree and forest resources are thus needed to provide statistics that demonstrate response to all three conventions and to measure progress in the management of trees and forests.

UN Member Countries also contribute to global forest and agriculture assessments undertaken on a fairly regular basis by FAO. Data produced through national assessments are used to produce regional and global synthesis on the state of the resources and their evolution. Such regional and global assessments are needed for monitoring the evolution of forest and agriculture resources, for identifying the contribution of each country and region to the objectives of sustainable development at world level, and for planning international support programmes for countries and regions that need assistance from the international community for more sustainable management of these resources. While methods and tools used for the assessments are clearly different from the farm, the sub-national and the national level, the purposes are the same: monitoring and planning.

1.4. FAO-FRA Role regarding Trees outside Forests

FAO-FRA Process for "Forests and Other Wooded Lands" – from 1946 to 2010

The objective of the Global Forest Resource Assessment programme (FRA) is to provide the data and information needed to support policies, decisions and negotiations in all matters where forests and forestry play a role (FAO 2010a). Since 1946, FAO publishes and shares global, regional and country information on the state of forest resources. Most of the data are contributed by member countries. Collating such data at global scale is a huge challenge, and FAO gradually acquired the expertise needed for this challenge, especially regarding consistent definitions, data collection methods and levels of precision. For instance FAO has organized numerous meetings with national and international experts to develop a global consensus regarding the terms and definitions needed for the global forest assessments (FAO, 2003, 2005).

FAO/FRA's assessment objectives, methods and requested information have improved in every successive run. In particular, FRA has adjusted to the evolving needs of countries and the increasing trends of deforestation and plantation forestry in the context of globalization, along with the emergence of biodiversity loss, carbon sequestration and poverty alleviation as global issues. In response to country needs and international needs, FAO has gradually integrated these themes into the FRA reporting framework proposed each five years to countries, and also into forest resource assessment programmes, such as the National Forest Monitoring and Assessment (NFMA) programme (http://www.fao.org/forestry/nfma/en/). FRA has also adjusted to the growing capacity of national institutions for collecting and analyzing the information

requested by users, gradually increasing the number of parameters in each theme, in recognition of their complexity.

These changes and improvements may be seen in the FRA 2010 global report, in which:

- ✓ A total of 233 countries and territories, grouped in 12 geographical regions were included.
- ✓ The reporting framework was based, as for FRA 2005, on the concept of sustainable forest management, which encompasses social, economic and environmental dimensions of forest resources that are assessed through 17 key variables (see Table 1).
- ✓ Close collaboration with other reporting processes helped to avoid duplication of effort for variables that are reported to several agencies. For example, further streamlining of reporting to FAO, the International Tropical Timber Organization (ITTO) and the Ministerial Conference for the Protection of Forests in Europe (now Forests Europe) was achieved.
- ✓ New variables enabled the assessment of progress towards the 2010 Biodiversity Target of the CBD and towards the four Global Objectives on Forests of the Non-legally Binding Instrument on all Types of Forests adopted by the United Nations General Assembly at its 62nd Session (UNGA, 2008).
- ✓ Methods for reporting on variables related to forest biomass and carbon were harmonized with the latest specifications and guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2006).
- ✓ Efforts have continued to establish and maintain globally consistent definitions in the FRA process, in order to ensure consistency over time and reduce the reporting burden on countries.

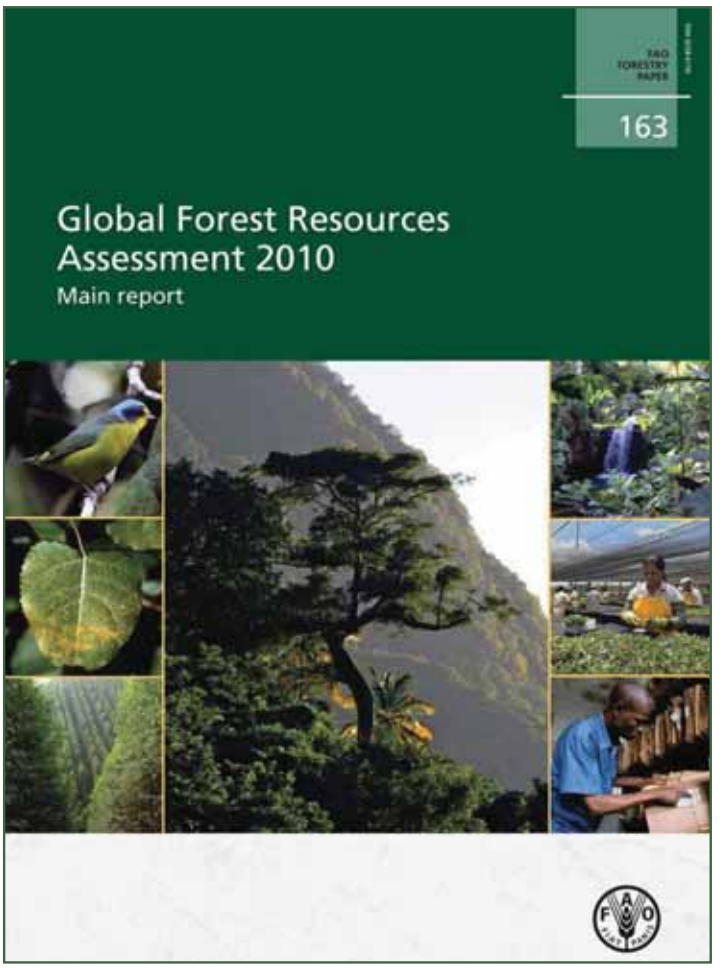


Table 1: FRA 2010 reporting tables and their links to the thematic elements of sustainable forest management (source: FAO 2010a. Table 1.1, p 4)

	Thematic elements						
Table 1	Extent of forest resources	Forest biological diversity	Forest health and vitality	Productive functions of forest resources	Protective functions of forest	Socio-economic functions of forest	legal, policy and institutional frameword
1. Extent of forest and other wooded land	✓	✓		✓			
2. Forest ownership and management rights						✓	✓
3. Forest designation and management		✓		✓	✓	✓	✓
4. Forest characteristics	✓	✓		✓	✓		
5. Forest establishment and reforestation	✓	✓		✓			
6. Growing stock	✓	✓	✓	✓			
7. Biomass stock	✓	✓		✓			
8. Carbon stock	✓			✓			
9. Forest fires	✓	✓	✓	✓	✓		
10. Other disturbances affectiong forest health and vitality	✓	✓	✓	✓	✓		
11. Wood removals and value of removal				✓		✓	
12. Non-wood forest products removals and value of removal				✓		✓	
13. Employment						✓	
14. Policy and legal framework							✓
15. Institutional framework							✓
16. Educational framework							✓
17. Public revenue collection and expenditure						✓	

FRA and Trees Outside Forests – 2000, 2005 and 2010.

The concept of "Trees outside Forests" emerged in 1995 to designate trees growing outside the forest and not belonging to Forest or Other Wooded Land (Bellefontaine et al., 2002). At that time, "attention tended to focus on the various components of this rather diffuse resource: agroforestry, silvopastoralism, urban and rural forestry, and other related disciplines. Trees outside forests were also overlooked in natural resource assessments, absent from statistics, policy and legislation, and barely mentioned in the public discourse" (Sène in Bellefontaine et al., 2002).

"The great promise of the sector for sustainable natural resource development and integrated forest, agricultural, pastoral and urban land management" (ibid 2002) prompted the Expert Meeting on Global Forest Resources Assessments, held in 1996 in Kotka, Finland (Kotka III), to recommend that FAO pursue hard data on trees outside forests (ibid 2002).

In response to these recommendations, the Trees outside Forests issue was included into the Global FRA 2000 process. FAO held an expert consultation on "enhancing the contribution of Trees outside Forests to sustainable livelihoods" in Rome in

November 2001, and various reports and publications were produced: an issue of Unasylva (vol 51-200) dedicated to Trees outside Forests, 2000-2001; Trees outside Forests – Towards rural and urban integrated resources management, FAO 2001b; the proceedings of the expert consultation (Sadio et al. eds, 2002); a training manual on inventory of trees outside forests (Rawat et al. 2003); and the FAO Conservation Guide 35, Trees outside Forests – Towards better awareness (Bellefontaine et al., 2002). The FAO Forestry Department also conducted regional training workshops such as a workshop on "Assessment of Trees outside Forests (TOF)" held in April 2002 in Dehradun, India (FSI, 2002), and carried out a project on "the role of planted forests and trees outside forests in landscape restoration in low forest cover countries" (FAO 2004).

In parallel with these efforts to raise awareness about Trees outside Forests, the FAO Forestry Department took two important initiatives that support the integration of Trees outside Forests into national assessments: it included Trees outside Forests into the programme developed to provide support to national forest monitoring and assessment (NFMA); and, In a first attempt to capture information on TOF at the national level, the FRA programme included a line on Other Land with Tree Cover, a subset of Trees outside Forests, –-in the country reporting tables to FRA (FRA 2005 and FRA 2010a).

By 2010, the FAO NFMA programme had directly supported more than 15 countries that have implemented national field inventories inside and outside forests (http://www.fao.org/forestry/17277-0404ecd56baa7684da1943aef014e4029.pdf). The number of countries and territories that filled the Other Land with Tree Cover (OLwTC) line increased from 61 in FRA 2005 to 77 in FRA 2010. In the meantime, research in agroforestry and urban forestry has gradually built a solid scientific corpus that demonstrates the importance of trees outside forests for the environment and for people's livelihoods (Konijnendijk, 2003; Jim and Chen, 2009; Idol et al., 2011; Schroth & MacNeely, 2011). However concerns remain about the scarcity of hard data on Trees outside Forests, especially at sub-national and national levels. For that reason the latest Expert Meeting on Global Forest Resources Assessments (Kotka 5, 2006) renewed its recommendation for more efforts and FAO-FRA included a thematic study on TOF in its FRA 2010 assessment.

1.5. Towards a comprehensive assessment of the tree and forest resources: "Wooded Lands" (Forest + OWL), and "Trees outside Forests" (on Other Land).

With the diversity and quality of data collected for the global forest resource assessments improving over time, the situation for TOF today may be compared to the situation for forests when FAO began its first assessments in 1945 (FAO, 1948). Growing acknowledgement of the potential economic importance of TOF, and recent political interest in their environmental services, could help improve the situation in the same way that forests gained attention. If the right steps are designed and efforts are made, a global assessment of TOF could well take place in a not-so-distant future, a global assessment with the same level of detail and quality as the current assessment of forest and other wooded land.

The themes that structure the FRA for Forest and Other Wooded Land are also relevant to TOF with some adaptations. These themes are embedded in the concept of sustainable forest management, and they encompass the social, economic and environmental dimensions of the forest resources. Similarly, the themes structuring a global TOF assessment should be embedded in the concept of sustainable management and should encompass the social, economic and environmental dimensions of the TOF resources. It is possible to propose a mirror theme for each of the seven themes developed for the FRA 2010 assessment, as in Table 2. For some themes the variables to be reported are straightforward. For instance, for "Extent of TOF resources," one just has to replace "forest" by "TOF" in the three main variables for the FRA 2010: area with TOF, growing stock of TOF, and carbon stock in living biomass. But for other themes such as "Biological Diversity", replacing "forest" with "TOF" in the variable makes no sense. What would be an area with "primary TOF"? It is however possible to find variables with a strong meaning relative to the theme. For instance, agroforestry systems such as agroforests and parklands allow conservation of many plant and animal species; the area covered with such systems could be proposed as an indicator of the contribution of TOF to biological diversity. This is what is proposed in Table 2.

It is important to note that the proposed variables in Table 2 are only indicative of what could be done. A collective effort will need to carve out the most relevant and informative variables for each theme, a collective effort similar to the participatory process implemented for years by FAO to improve the data collected on forests for the global FRA.

Table 2: The 7 FRA 2010 themes, their associated variables, and their proposed equivalent for a future global TOF Assessment (adapted from FAO 2010a. Table 1, p. xxviii)

Themes for FRA 2010	Proposed themes for a global TOF assessment
Extent of forest resources • Area of forest • Growing stock of forests • Forest carbon stock in living biomass	**Extent of TOF resources** • Area with TOF ◦ Area with TOF on agricultural land ◦ Area with TOF on urban land ◦ Area with TOF on non urban/non agricultural land • Growing stock of TOF • Carbon stock in living TOF biomass
Forest biological diversity • Area of primary forest • Area of forest designated primarily for conservation of biodiversity • Area of forest within protected areas	**TOF biological diversity** • Area of TOF systems with high biodiversity value such as agroforests and agroforest parklands • Number of tree species involved in TOF systems
Forest health and vitality • Area of forest affected by fire • Area of forest affected by insects (and diseases?)	**TOF health and vitality** • Area with TOF affected by fire • Area with TOF affected by insects and diseases
Productive functions of forest resources • Area of forest designated primarily for production • Area of planted forest • Total wood removals	**Productive functions of TOF resources** • Total wood removal from areas with TOF • Total non wood removal from areas with TOF (by category: fruit, gum latex and resin, leaf, bark)
Protective functions of forest resources • Area of forest designated primarily for protection of soil and water	**Protective functions of TOF resources** • Area with TOF ensuring protection of soil and water
Socio-economic functions of forests • Area of forest under private ownership • Value of total wood removals • Employment in primary production of goods	**Socio-economic functions of land with TOF** • Area with TOF under private or/and community ownership • Area with TOF under State ownership • Value of total wood removals from TOF • Value of total non-wood removals from TOF • Employment in primary production of goods from TOF
Legal, policy and institutional framework • Forest area with management plan • Human resources in public forest institutions • Number of students graduating in forestry	**Legal, policy and institutional framework** • Area with TOF under disputed ownership status • Human resources in public institutions dealing with TOF • Number of students graduating in agroforestry and in urban forestry

1.6. The Present Thematic Report

Trees Outside Forests (TOF) have important economic, social and environmental implications, at local, national, and international scales. In the current context of change, their importance will increase dramatically for people's livelihoods and national economies, and also for various international processes that address global environmental and economic challenges: carbon sequestration, biodiversity loss, desertification, poverty alleviation. Yet TOF are not consistently considered in national policies and land-use planning decisions. The reason most often cited is that TOF have not been appropriately assessed so that the localization, extent, forms, natures, economic and ecological roles of the TOF resources are generally not well known beyond the local level. Assessing TOF poses different challenges than assessing forests, especially the variability and heterogeneity of TOF systems, their sometimes sparse distribution and limited spatial footprint, and complex ownership and institutional arrangements. In most countries the resulting paucity of TOF data accessible to managers and policy makers limits the choices on tree-related investments at every level from sub-national to national and international levels.

Through the Expert Consultation on Global Forest Resources Assessments (Kotka V, June 2006) countries expressed their need for support with methods and techniques allowing a better assessment of TOF resources. They mandated FAO for undertaking a Thematic Study on TOF as part of FRA 2010, including the formulation of technical guidelines for better integrating TOF into the FRA 2015 reporting process. Through a focus on TOF assessment, this thematic report aims to enable the provision of information on TOF (status and evolution) in time and quality, in order to make informed decisions for the optimization of tree and forest resources for sustainable development and food security.

FAO organized an Inception Workshop on the Thematic Study on TOF, held in FAO headquarters in Rome, Italy in June 2010. In attendance were 42 experts from 17 countries, coming from governmental organizations, international (CATIE, ICIMOD, ICRAF, IFAD, IUFRO, AU Commission, World Bank) and national institutions (CIRAD, IRD), universities and NGOs (Annex 1: List of participants) to define the objectives, the scope and the development process of the study.

The workshop recommended that the study supports national agencies responsible for forestry, agriculture, environment, and rural and urban development, by providing tools and methods to assess resources of trees outside forests, their products, uses and economic and environmental functions, at a national level.

The workshop also recommended:

- ✓ that the Report should provide countries with a typology, a set of variables and a set of assessment methods for TOF that allow reporting compatibility with the main international processes such as the UNFCCC, the CBD, and the FRA;
- ✓ that the typology and list of variables for TOF should be developed through a methodology that facilitates countries to choose the level of detail they want;
- ✓ that methods used for past and current TOF assessment should be evaluated in terms of performances and costs;
- ✓ that the Thematic Study should be developed around two main tasks:

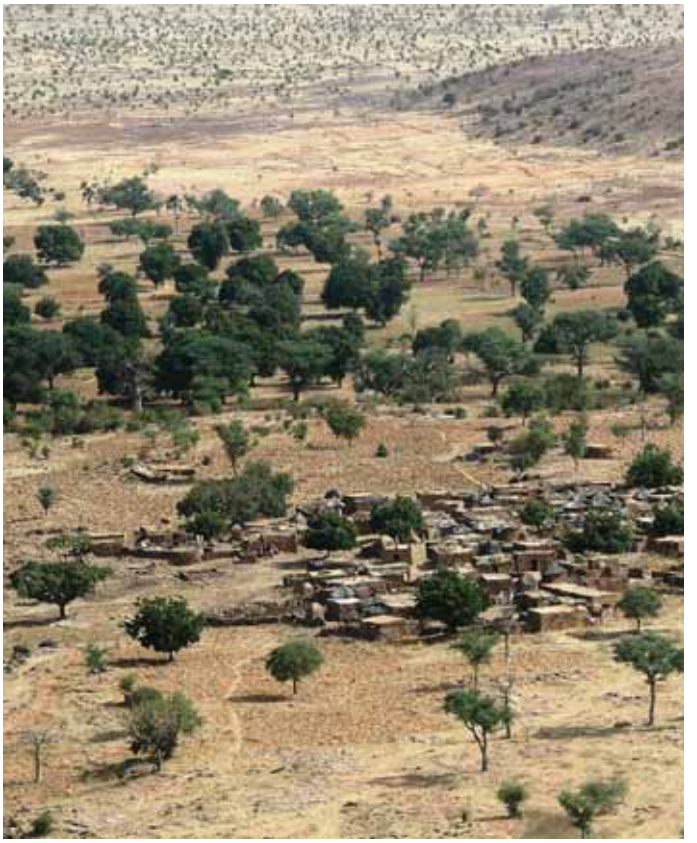
- task 1: Review past and current large-area TOF assessments as a basis for formulating technical and methodological options for countries to undertake their TOF assessments;
- task 2: Develop a conceptual framework for assessing TOF, including a typology and a set of variables on which countries can (i) superimpose their objectives and (ii) select technical and methodological options adapted to their needs and resources.

The present thematic report, written in accordance with the Inception Workshop recommendations, consists of three main parts:

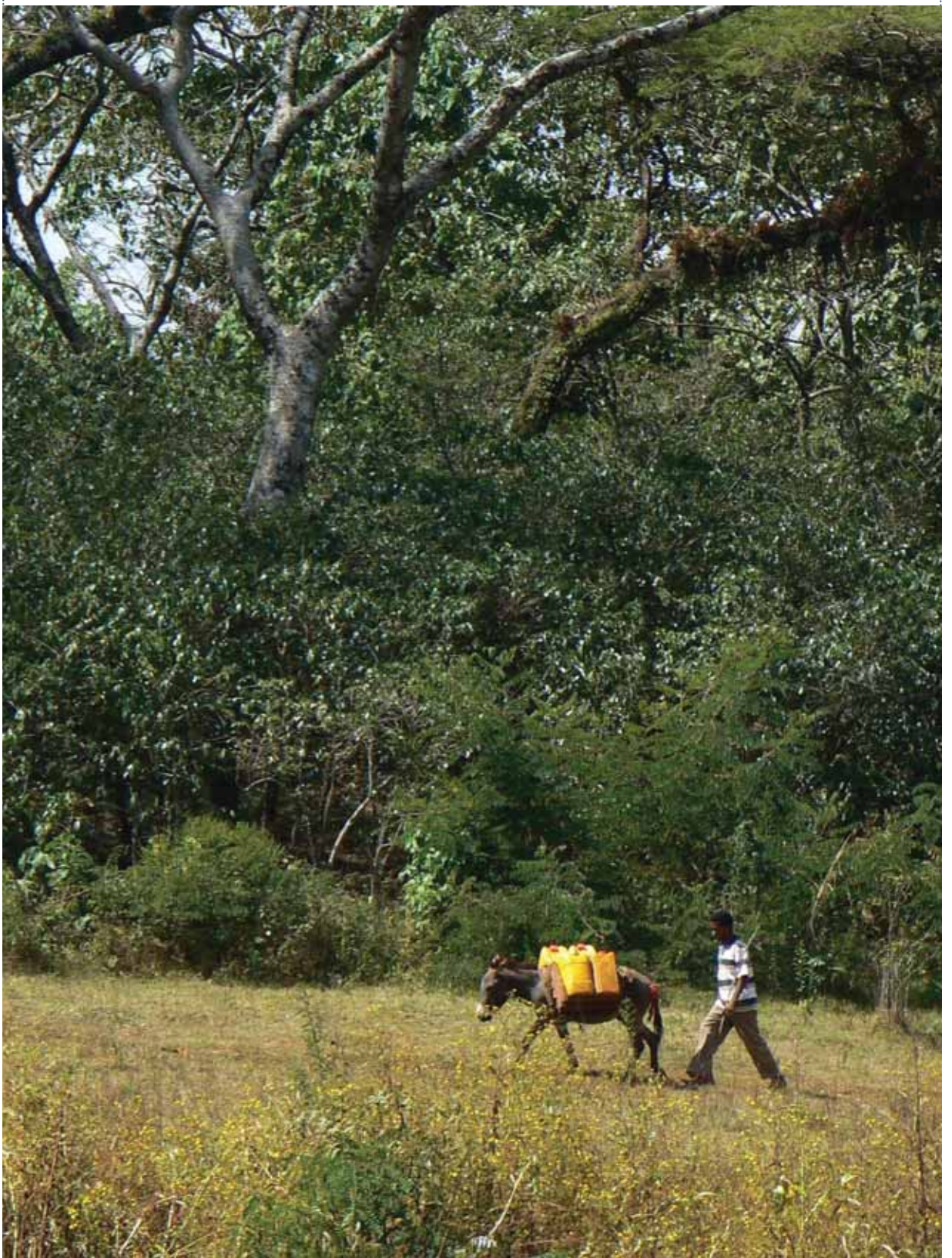
Part One is the report itself. Following this introductory chapter, Chapter 2 discusses the position of TOF and land with TOF in the FAO land classificatory framework. It proposes a formal definition of land with TOF as a subcategory of Other Land called "Other Land *with TOF*". It analyses the various subsets of this sub-category, derives a "natural" typology of land with TOF and proposes an operational definition of TOF and a decision tree tool for easy classification of any piece of land with trees using the FAO classification framework. Chapter 3 reviews a set of large-area assessments that include or may include TOF. Thirty-eight assessments using various methods and targeting different TOF groups have been reviewed including 1 global scale, 1 regional scale, 33 national scale and 3 sub-national scale. Chapter 4 builds on the results and conclusions of chapters 2 and 3 to propose options for countries that would like to implement a large-area TOF assessment, depending on their existing data, their objectives, and their human and financial resources. Chapter 5 presents the main conclusions of the study and some recommendations.

Part Two of this report is a compendium of the assessments and international support programmes that have been collected for case studies for review in Chapter 3 of Part 1. Each assessment is presented in a synthetic standardized format, with most assessments grouped by country. The 38 large area assessments correspond to 19 countries distributed over 10 of the major World regions. In addition, 4 international support programmes that may provide support for TOF assessments are reviewed and presented also in a synthetic format.

Part Three, called TOF illustrated, presents satellite images illustrating the various subsets of Other Land *with TOF* and how they can be identified. This part offers an illustrated guide to TOF, with the aim of facilitating often difficult classificatory distinctions between Forest, Other Wooded Land, and Other land *with TOF*.



2. TOF and Land with TOF



2.1. Introduction

There are many valid ways of classifying land cover into discrete, mutually exclusive categories. Similarly, there are many valid ways of defining a forest, and each country has its own definition. Regardless of which definition is used, the category "forest" never contains all the trees in a landscape. There are always trees growing outside "forest" and thus not counted when forests are inventoried and assessed.

In its endeavour to assess forest resources globally, FAO uses an internationally accepted definition of "forest" that countries likewise use in reporting to the FAO's Global Forest Resource Assessment (FRA). FAO developed another forest-like category for reporting purposes: "Other Wooded Land" (OWL). These two categories together still do not comprise all the trees, in particular trees growing on agricultural land and in settlements. In many countries, these trees fall outside both the "forest" and "OWL" categories yet they represent an important and growing share of the wood resource because of forest conversion. They also form a resource that is increasingly acknowledged as important for livelihood and the environment. Thus for the Global Forest Resource Assessment 2000, FAO - FRA coined the expression "Trees Outside Forests" (TOF) to designate those trees that grew neither in "forest" nor on "OWL".

TOF, or more precisely Land with TOF, as a category, should thus be understood in reference to the FAO-FRA classification scheme (Figure 1), and especially in reference to its two main forestry categories: "Forest" and "Other Wooded Land." The definitions of these two categories have slightly evolved since 2000[1], which means that TOF as a category has also evolved and needs to be clarified, although the definition of TOF given by FAO in Bellefontaine et al. (2002) remains valid: "Trees outside forests refer to trees[2] on land not defined as Forest and Other Wooded Land."

After this short clarification of the TOF concept, the rest of this chapter is devoted to identifying the "Trees Outside Forests" realm. It includes:

- ✓ an analysis of the definitions needed to define TOF;
- ✓ a proposed operational definition of Other Land *with TOF* as a subcategory of Other Land;
- ✓ a definition-derived typology of Land with TOF;
- ✓ the presentation of a practical decision tool for an easy and rigorous classifying of the various types of land cover with trees;
- ✓ a clarification of the position of the only TOF category currently reported in FAO-FRA (Other Land with Tree Cover) in the TOF realm.

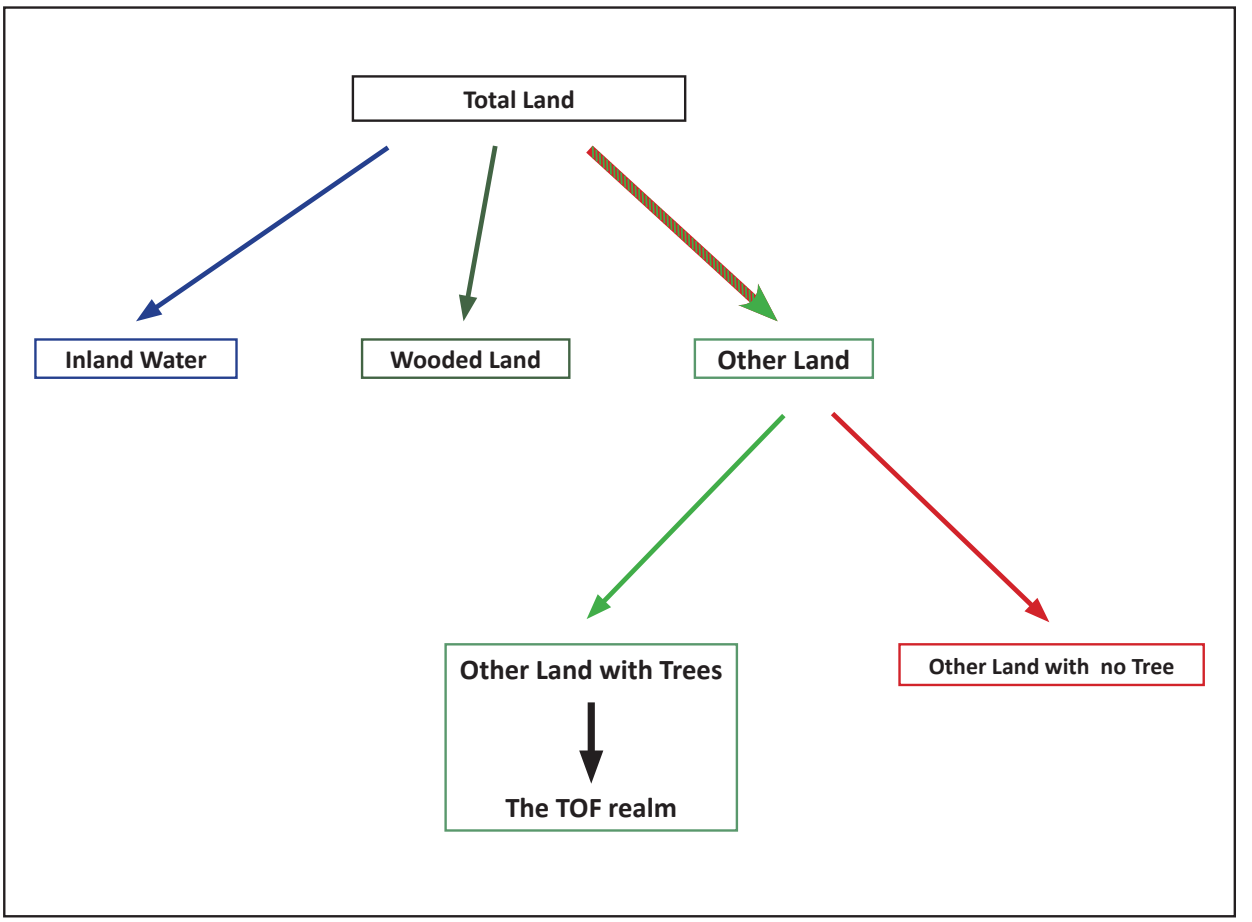
1 The definition of "forest" has strongly evolved since the first FAO international forest assessment. For instance in its 1968 World Forest Inventory, FAO defined "forest land" as "all land with a 'forest cover', that is with trees whose crowns cover more than 20% of the area and that is not used primarily for purposes other than forestry" (Husch, 1968).

2 "Tree" in this definition includes both trees and shrubs.

2.2. Defining TOF and Land with TOF

"Land with TOF" is a category defined as distinct from "Forest" and "Other Wooded Land", but also in relation with "Other Land." Definitions of these three mutually exclusive categories are thus needed to characterize the coverage of TOF and to propose an operational definition.

Figure 1: The FAO-FRA land classification framework and the position of TOF



2.2.a. FAO/FRA Definitions (FAO 2010b)

Forest *(lands) (FOR)*:

Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

Explanatory notes:

1. Forest is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m in situ.
2. Includes areas with young trees that have not yet reached but which are expected to reach a canopy cover of 10 percent and tree height of 5 m. It also includes areas that are temporarily unstocked due to clear-cutting as part of a forest management practice or natural disasters, and which are expected to be regenerated within 5 years. Local conditions may, in exceptional cases, justify that a longer timeframe is used.
3. Includes forest roads, firebreaks and other small open areas ; forest in national parks, nature reserves and other protected areas such as those of specific environmental, scientific, historical, cultural or spiritual interest.
4. Includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m.
5. Includes abandoned shifting cultivation land with a regeneration of grees that have, or is expected to reach, a canopy cover of 10 percent and tree height of 5 m.
6. Includes areas with mangroves in tidal zones, regardless of whether this area is classified as land area or not.
7. Includes rubber-wood, cork oak and Christmas tree plantations.
8. Includes areas with bamboo and palms, provided that land use, height and canopy cover criteria are met.
9. Excludes tree stands in agricultural production systems, such as fruit tree plantations, oil palm plantations and agroforestry systems where crops are grown under tree cover. Note: Some agroforestry systems such as the Taungya system where crops are grown only during the first five years of the forest rotation should be classified as forest.

Other Wooded Land (OWL):

Land not classified as Forest, spanning more than 0.5 ha; with trees higher than 5 m and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

Explanatory notes:

1. The definition above has two options:
   - The canopy cover of trees is between 5 and 10 percent; trees should be higher than 5 m or able to reach 5 m in situ.

   or
   - The canopy cover of trees is less than 5 percent but the combined cover of shrubs, bushes and trees is more than 10 percent. Includes areas of shrubs and bushes where no trees are present.
2. Includes areas with trees that will not reach a height of 5 m in situ and with a canopy cover of 10 percent or more, e.g. some alpine tree vegetation types, arid zone mangroves, etc.
3. Includes areas with bamboo and palms, provided that land use, height and canopy cover criteria are met.

Other Land:

All land that is not classified as Forest or Other Wooded Land.

Explanatory notes

1. Includes agricultural land, meadows and pastures, built-up areas, barren land, land under permanent ice, etc.
2. Includes all areas classified under the subcategory "Other land with tree cover."

Three terms – tree, shrub (or bush, considered here as a synonym) and canopy cover- are extensively used in the above definitions. Defining these terms (FAO-2010b) is also necessary to clarify the concepts of TOF and Land with TOF:

Canopy cover
The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants. Cannot exceed 100 percent. (Also called crown closure.) Same as crown cover.

Tree

A woody perennial with a single main stem, or in the case of coppice with several stems, having more or less definite crown.

Explanatory note: Includes bamboos, palms, and other woody plants meeting the above criteria.

Shrub

Woody perennial plant, generally more than 0.5 m and less than 5 m in height at maturity and without a definite crown. The height limits for trees and shrubs should be interpreted with flexibility, particularly the minimum tree and maximum shrub height, which may vary between 5 m and 7 m.

2.2.b. Analysis of the FAO-FRA definitions

The six above terms and their definitions are necessary and sufficient to define TOF and where they are located. The following points are direct consequences of these definitions:

✓ TOF includes not only trees outside "Forest", but also trees outside "Other Wooded Land".

✓ TOF includes not only trees, but also shrubs!. In "Other Wooded Land", the cover may be made-up of shrubs that cannot reach 5 m high, as long as the canopy cover threshold is reached. This inclusion of shrubs in one of the two "forestry" categories comes in strong support of the inclusion of shrubs in TOF.

✓ TOF can only be found in "Other Land".

✓ Any tree growing in "Other Land" qualifies as a TOF.

✓ All trees and shrubs on land under agricultural or urban land use are TOF, including:

- Trees and shrubs that grow on "land that is predominantly under urban land use" are TOF, because such land is excluded from the definitions of both "Forest" land and "Other Wooded Land".
- Trees and shrubs that grow on "land that is predominantly under agricultural land use" are TOF, because such land is excluded from the definitions of both "Forest" land and "Other Wooded Land".
- Bamboos and palms that grow on "land that is predominantly under agricultural or urban use" are TOF (see explanatory note 8, definition of "Forest", note 3, definition of "Other wooded Land", and note 1, definition of "Tree").

✓ TOF are also associated to some non-agricultural/non-urban land uses, including:

- Trees – more than 5m high or able to reach this threshold in situ - that grow on "land that is not predominantly under agricultural or urban use" are TOF if the land spans less than 0.5 ha, whatever the canopy cover (see definition of "Forest").
- Trees – more than 5m high or able to reach this threshold in situ - that grow on "land that is not predominantly under agricultural or urban use" are TOF if they form windbreak, shelterbelt or corridor less than 20 m width (see explanatory note 4, definition of "Forest").
- Trees – more than 5m high or able to reach this threshold in situ - that grow on "land that is not predominantly under agricultural or urban use" are TOF if their canopy cover is less than 5 percent, whatever the land area they span on (see definition of "Other Wooded Land").
- Trees and shrubs that grow on "land that is not predominantly under agricultural or urban use" are TOF if their combined canopy cover is less than 10 percent, whatever the land area they span on (see definition of "Other Wooded Land").

2.2.c. TOF typology: TOF subsets and associated tree-based systems

The TOF realm can now be inferred from the analysis above. Three major and distinct TOF sets collectively make up the TOF realm: TOF on agricultural land (AGRI), TOF on urban land (URB), and TOF on non-urban and non-agriculture land (NON A/U). The last set may itself be subdivided into four TOF subsets (figure 2).

Set 1: TOF on Agriculture Land (TOF-AGRI)

✓ TOF-AGRI includes all lands predominantly under agricultural use with trees and/or shrubs whatever their spatial pattern (in line, in stands, scattered), irrespective of area, height, strip width, and canopy cover level. It includes all agroforestry systems except those which main purpose is forestry; it includes also all non forestry tree crop plantations and orchards.

Set 2: TOF on Urban Land (TOF-URB)

✓ TOF-URB includes all lands predominantly under urban use with trees and/or shrubs whatever their spatial pattern (in line, in stands, scattered), irrespective of area, height, strip width, and canopy cover level. It includes trees in private gardens, in parks, along streets, in parking lots, etc.

Set 3: TOF on Non Agricultural/Non Urban Land (TOF-NON A/U))

✓ TOF-NON A/U includes all lands not predominantly under agricultural or urban use, and outside forests, with:

- Subset 1: small tree stands (area<0.5 ha), irrespective of trees and/or shrubs spatial organization, height and canopy cover level;
- Subset 2: linear tree formations, narrow (width <20 m), irrespective of area, plant height and canopy cover level;
- Subset 3: large stands (area ≥ 0.5 ha), trees (height ≥ 5 m) with low canopy cover level (cc < 5 percent);
- Subset 4: large stands (area ≥ 0.5 ha), shrubs and/or small trees (height <5 m) with low canopy cover level (cc < 10 percent).

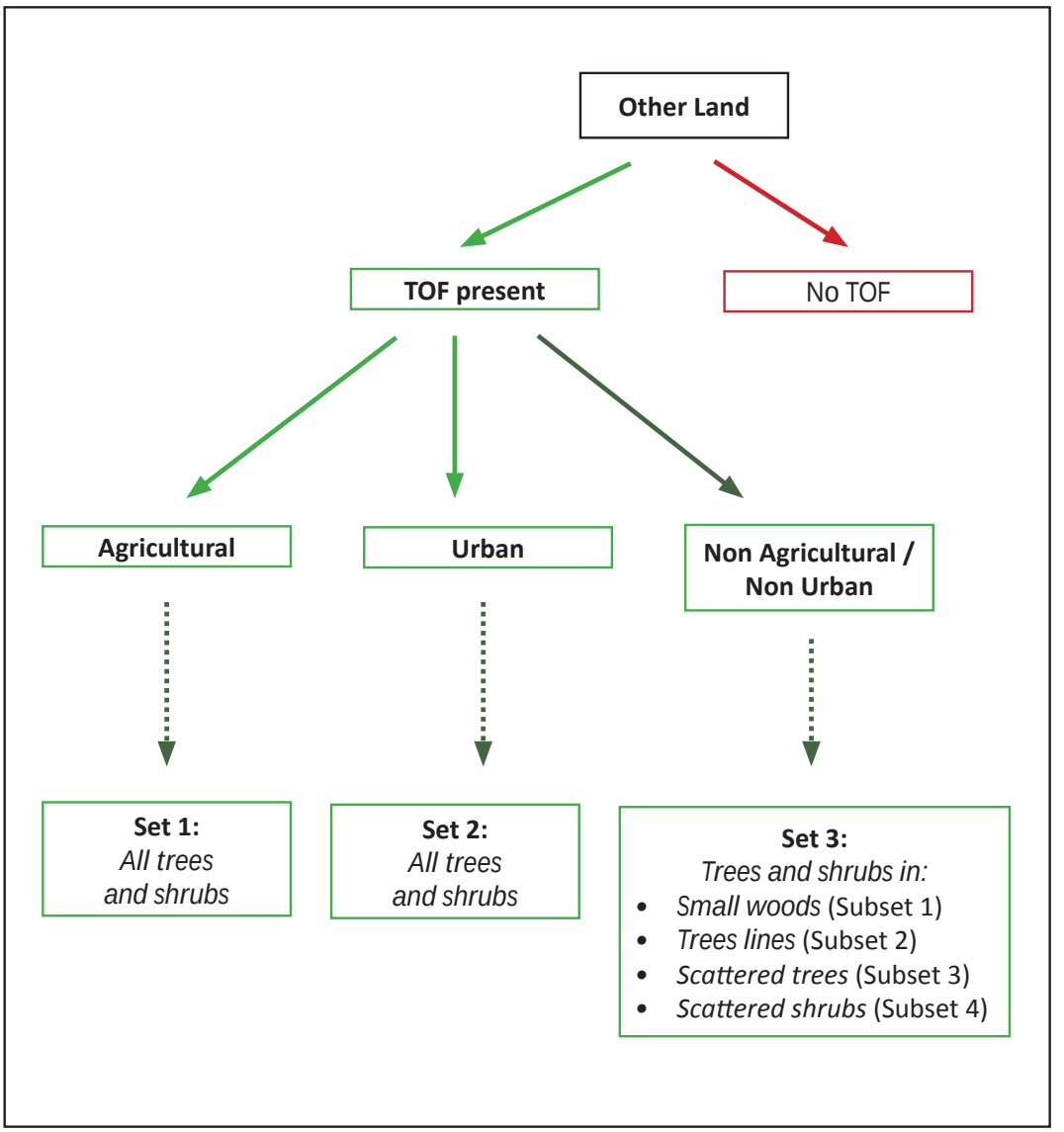
By definition all trees and/or shrubs on agricultural land (TOF-AGRI) and on urban land (TOF-URB) are TOF, irrespective of plant height, patch area, width or canopy cover. Trees on agricultural land and on land under urban use may be planted or not, and may occur with various densities and under various spatial patterns (see part 3: satellite images of examples of TOF AGRI and TOF URB in various countries).

TOF on Non-Agricultural / Non-Urban land may be divided into two groups:

✓ Subsets 1 and 2 are typically small patches, or lines, of trees and/or shrubs. Trees and shrubs may be planted or naturally established, and may be encountered in a large variety of situations, independently from the local environmental tree growth conditions (see part 3: satellite images of small woods, small woodlots, tree lines along roads, hedges, trees along river, for example in Burkina Faso).

✓ Subsets 3 and 4 are made up of large patches consisting exclusively of scattered trees or shrubs. On land that is not under urban or agricultural use, such patches are mainly encountered in natural environments involving harsh growing conditions resulting in low tree and/or shrub height and canopy cover (see part 3: satellite images of examples of scattered trees and bushes, mainly in arid countries).

Figure 2: The formal position of TOF and TOF subsets within Other Land



2.2.d An operational definition of Other Land *with TOF*

In the FAO-FRA classificatory framework, all categories should be mutually exclusive. Integrating TOF or more precisely "Other Land *with TOF*", into the current framework thus requires subdividing "Other Land" into two mutually exclusive sub-categories. It is proposed to call these two sub-categories:

- "Other Land *with TOF*" (OL*wTOF*)
- "Other Land *with No TOF*" (OL*wNoTOF*)

The above analysis (2.2.b) allows formulating a formal –based only on logical inferences- definition of Other Land *with TOF*: Land classified as Other Land, i.e. not classified as Forest or Other Wooded Land, with trees and/or shrubs. It includes land that is predominantly under agricultural or urban use as long as trees and/or shrubs are present. It also includes land that is not predominantly under agricultural or urban use when area and/or tree and shrub canopy cover are below the thresholds that define "Forest" and "Other wooded Land".

In land-use classifications, categories must be unambiguous, clear, and operational. It must thus take into account technological limitations and also the balance between time (and cost) efficiency and the degree of precision of the results.

The formal definition of "Other Land *with TOF*" given above is obviously not operational. It would imply that any piece of Other Land supporting some trees and/or shrubs, whatever the density of TOF, whatever the area of Other Land, would be classified as Other Land *with TOF*. The risk is thus quite high of having almost all Other Land classified as Other Land *with TOF*. Although logically correct, the formal definition would in practice result in detrimental ambiguities in selecting the reference area associated with TOF during assessments. For instance, should a one hectare piece of land with one tree be classified as one hectare of Other Land *with TOF*, or should it be divided into two pieces, one classified as Other Land *with no TOF* and one classified as Other Land *with TOF*? And if the latter, how could one decide the area of each piece?

The definitions of Forest and Other Wooded Land are conceived as operational definitions: they include minimum thresholds, for the height of trees, for the area to be considered, for the canopy cover percentage, etc. Minimum values – for area, canopy cover and for length and width of narrow tree lines- are also needed to define Other Land *with TOF* in an operational and unambiguous manner.

The following minimum threshold values for the subcategory Other Land *with TOF* are thus proposed:

✓ Canopy cover threshold: 5 percent if trees only, 10 percent if combined cover of trees and shrubs

The definition of a canopy cover (cc) threshold for Other Land with TOF is absolutely necessary for operational and assessment cost-effectiveness reasons. This threshold would create a distinction between areas where TOF density is sufficient to be labeled as Other Land *with TOF*, and areas where TOF density is not sufficient. Below the cc threshold, the area would be labeled Other Land *with No TOF*, even if TOF are present.

TOF refers to trees and shrubs, so by analogy with what has been done for OWL, it is suggested to adopt the same canopy cover threshold: 5 percent if only trees, 10 percent in case of a combined cover of trees and shrubs.

✓ Area threshold: 0.05 ha
There is no obvious rationale for selecting one minimum area threshold over another. The value 0.05 ha is suggested here to allow classifying most smallholder farmers' woodlots as Other Land with TOF.

✓ Tree line length threshold: 25 m
Some country assessments have used the value 25 m (for example, Italy - see part 2). This value is suggested here by analogy with the length threshold for a tree line to be classified as Forest (see explanatory note 4, definition of Forest).

✓ Tree line width threshold: 3 m
The threshold value of 3 m, used in some country assessments such as in Italy (see part 2) is proposed here as the minimum width for a tree line. Tree lines with a width ≥ 20 m and a length ≥ 25 m are classified as Forest (see explanatory note 4, definition of Forest), if they are not under agricultural or urban use.

The suggested thresholds, combined with the above analysis of the FAO-FRA classificatory categories, allow to propose operational definitions for the two mutually exclusive sub-categories that compose Other Land: Other Land *with TOF* and Other Land *with no TOF*.

Other Land *with TOF* (OL*wTOF*) - subcategory of Other Land:

Land classified as Other Land (i.e. not classified as Forest nor Other Wooded Land), spanning more than 0.05 ha with trees higher than 5 m and a canopy cover above 5 percent, or with trees able to reach these thresholds in situ; or with a combined cover of shrubs and trees above 10 percent.

Explanatory notes:

1. Includes land that is predominantly under agricultural land use if it meets the area and tree/shrub canopy cover thresholds.
2. Includes land that is predominantly under urban land use if it meets the area and tree/shrub canopy cover thresholds.
3. On land that is not predominantly under agricultural or urban use, includes:
   - Areas spanning less than 0.5 ha and more than 0.05 ha
   - Windbreaks, shelterbelts and corridors of trees and shrubs, with an area spanning less than 0.5 ha or a width of less than 20 m but more than 3 m.

Other Land *with No TOF* (OL*wNoTOF*) - subcategory of Other Land:

Land classified as Other Land, but not classified as Other Land *with TOF*.

Explanatory notes:

1. Includes inland water bodies, barren land, stone outcrops, snow caps and glaciers, deserts, peat bogs, meadows without trees, annual crops without trees, etc...
2. Includes large areas with much scattered trees or shrubs (canopy cover < 5 percent if only trees are present; <10 percent if trees and shrubs are combined).
3. Includes very small areas with trees and/or shrubs (area <0.05 ha).
4. Includes very narrow (<3 m width) and very short (<25 m length) tree lines.

It is important to note that by adopting minimum thresholds, the subcategory "Other Land *with TOF*" implicitly leaves out some TOF, just as the category "Forest" does not include all forest patches: it omits those that fall below the 0.5 ha threshold.

The decision tree algorithm in Figure 2.3 can help clarify decisions in classifying any given piece of land into "Forest", "Other Wooded Land", "Other Land *with No TOF*", or "Other Land *with TOF*." This decision tree, based on the sequential application of the criteria in the FAO-FRA framework, suits the particular land use categories, definitions, set of decision criteria, as well as the current thresholds used by FAO-FRA and the proposed thresholds.

The decision tree algorithm is insensitive to changes in the spatial scale (resolution) at which land is being inspected (or mapped). Other countries and institutions using different criteria, sequencing and thresholds can adapt the decision tree concept to their own conditions.

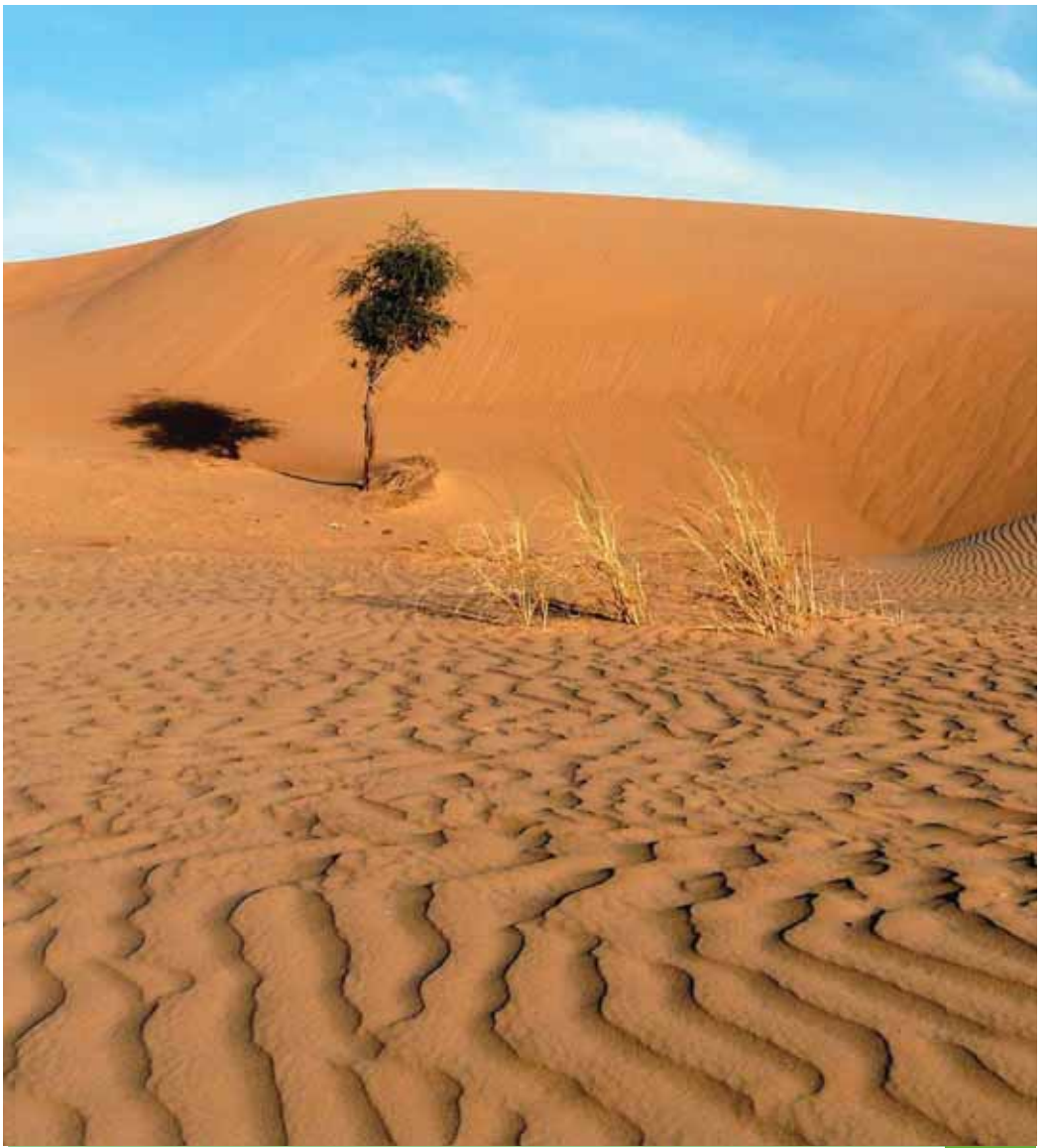
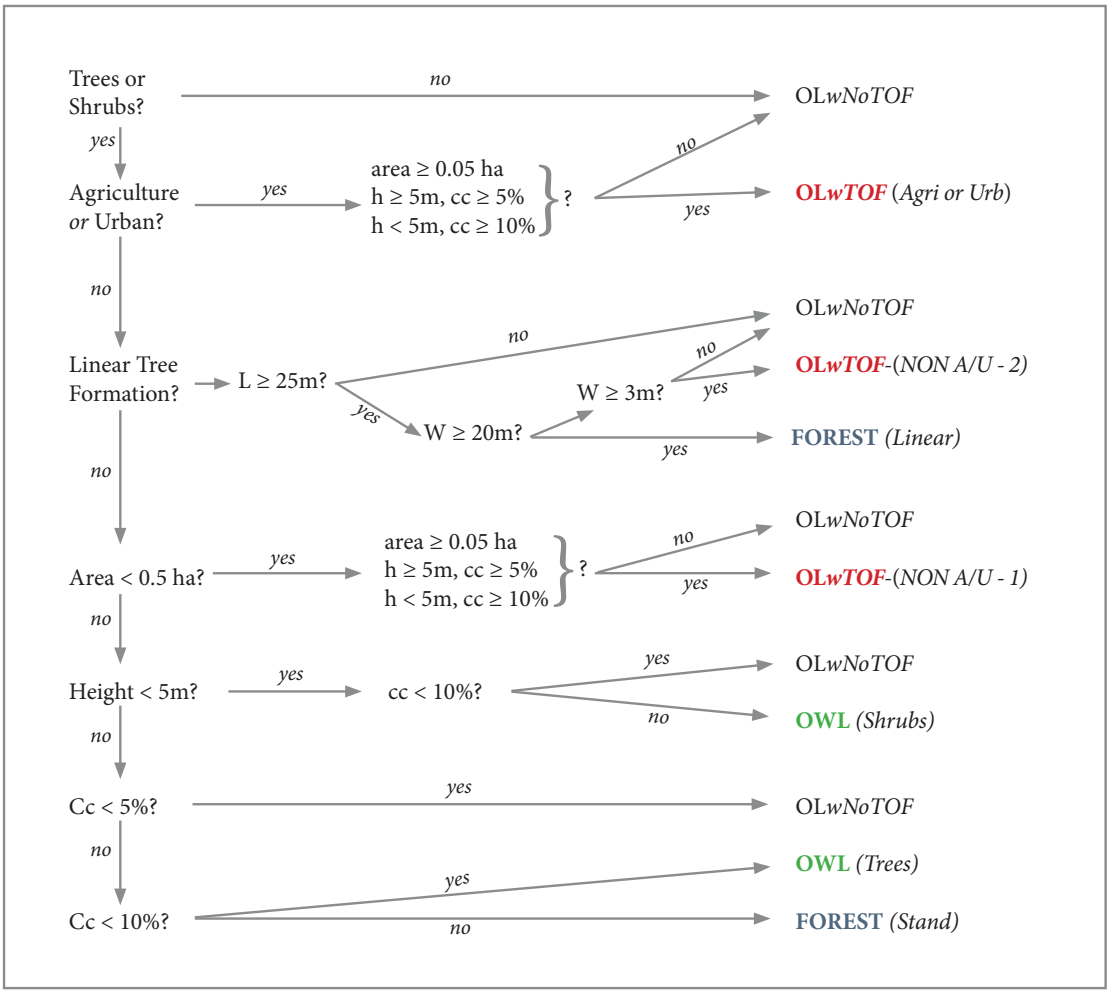


Figure 3: A Decision Tree Algorithm for the identification of Forest, Other Wooded Land, Other Land *with TOF* and Other Land *with No TOF*



Seven (minimal and sufficient) decision criteria were deducted from the FAO-FRA definitions and used to construct the decision tree algorithm for classifying land as
Forest (FOREST),
Other Wooded Land (OWL),
Other Land *with TOF* (OL*wTOF*),
Other Land *with No TOF* (OL*wNoTOF*).

The seven decision criteria (in parentheses the levels for each criterion) were:
1 = Presence of Trees or/and Shrubs on the land (yes/no).
2 = Land Use (Urban [URB] / Agriculture [AGRI] / Other = Non A/U).
3 = Spatial pattern of Trees or/and Shrubs (linear tree formation / other pattern).
4 = For linear tree formations: Length (L, threshold: 25 m) and Width (W, thresholds: 3 and 20 m).
5 = Trees or/and Shrubs patch area (thresholds: 0.05 and 0.5 ha).
6 = Trees or Shrubs height at maturity (threshold: 5 m).
7 = Trees or Shrubs canopy cover (thresholds: 5 % for Trees, 10% for Shrubs and small trees).

2.3. Removing remaining ambiguities

The above definitions are strictly inferred from the proposed thresholds and from the current definitions of "Forest," "Other Wooded Land" and "Other Land." The resulting rigorous framework allows classifying any piece of land in one or another of the classes of the FAO-FRA framework.

Some ambiguities however remain regarding some terms used in the definitions of "Forest" and "Other Wooded Land" and their explanatory notes. These ambiguities complicate the position of a few land-uses/land-covers, such as shifting cultivation, rubber plantations, agroforestry systems, and linear tree formations. Another major remaining ambiguity involves the absence of clear guidelines for a common understanding of the expressions agricultural land-use and urban land-use, which may lead different countries to classify pieces of land with the same land-use/land cover differently.

Problems linked to the above land-uses and the lack of unambiguous identification of agricultural and urban land-uses, are examined below. When possible, keys to help make objective decisions are given, with recommendations to relieve the remaining ambiguities and promote objective classification.

2.3.a. Shifting cultivation.

Since the studies of Conklin on Hanunoo agriculture (1957), shifting cultivation is recognized as an agricultural system in its own right. Conklin (1961) defines shifting cultivation a minima "as any continuing agricultural system in which impermanent clearings are cropped for shorter periods in years than they are fallowed". Many definitions have been proposed since then, along with synonyms such as "swidden cultivation", that complement Conklin's, especially in acknowledging the role of fallow in restoring the fertility of the soil-vegetation complex. It is important to note that all definitions recognize fallow as an integral and necessary part of shifting cultivation systems. It is also important to note the woody character of fallows in the humid tropics, character which has been integrated into some recent definitions: Mertz et al. (2009) for instance "define swidden cultivation in Southeast Asia as a land use system that employs a natural or improved fallow phase, which is longer than the cultivation phase of annual crops, sufficiently long to be dominated by woody vegetation, and cleared by means of fire."

In the FAO-FRA classificatory framework, "Abandoned shifting cultivation land with a regeneration of trees that have, or are expected to reach, a canopy cover of 10 percent and h= 5 m" is currently classified as forest (see definition of Forest, explanatory note 5). It seems simple, but in practice bear in mind that most lands under shifting cultivation are cropped over many crop/fallow cycles. Remember also that it is always very difficult to confirm that shifting cultivation land has been effectively abandoned, since any fallow land may appear abandoned: nothing looks more like abandoned shifting cultivation land than a fallow that will soon be cleared and which is still integral to an active shifting cultivation crop/fallow cycle system. In the humid tropics, this problem is even more difficult because fallow vegetation is usually quickly dominated by pioneer trees that develop as young secondary forests which easily reach the size and canopy cover thresholds of Forest.

It is thus strongly recommended that, in the humid tropics, young secondary forests less than 15-20 years old be classified as "Other Land *with TOF*" by default, provided they meet OL*wTOF* thresholds. It is also strongly recommended that these young secondary forests be classified as "Forest" only if field interviews have demonstrated either that they correspond to abandoned fallows getting out of the shifting cultivation cycle, or that they result from a process other than shifting cultivation.

2.3.b. Rubber plantations.

Rubber plantations are not easy to classify: the explanatory note 7 of the definition of Forest says that the category "includes rubber-wood[1]… plantations", if canopy cover and area thresholds are reached. This is quite ambiguous, since rubber-wood plantations – plantations of rubber for its wood as a primary product - are still quite anecdotal. On the contrary, rubber plantations –plantations of rubber for its latex as a primary product - cover millions of hectares, especially in Asia. These rubber plantations, whether they are monocrop plantations or mixed species agroforest plantations, can all produce rubber-wood as an end product when plantations are regenerated. This rubber-wood is however always a "secondary product." Until 1997, rubber was considered as an "agricultural cash crop" (FAO 1997) and rubber plantations were considered as "non-forest plantations" (FAO 1993). Its status changed with the FRA 2000, when it was decided to include rubber tree plantations into the reporting of the area under Forest, although the 2000 definition of Forest was already loaded with the ambiguity of the term "rubber-wood" (FAO 2001a). In practice, countries now report to FRA their area of rubber plantations under the category Forest, at least for monocrop plantations.

It is strongly recommended to remove the ambiguity still present in the explanatory note accompanying the definition of "Forest", either by changing the term "rubber-wood" into "monoculture rubber" and to conserve monoculture rubber in the "Forest" category, or by returning plantations to agriculture and to consider all land supporting rubber plantations (whatever their management, i.e. including monoculture plantations and agroforests) as "Other Land *with TOF*", provided they meet the OL*wTOF* thresholds.

1 Underlined by the authors

2.3.c. Linear tree formations.

Linear tree formations include shelterbelts, windbreaks, living fences, hedges, tree lines, etc. It is not easy to classify them as Forest or as Other Land, and it is always necessary to consider first the land-use, agricultural, urban, or non agricultural/non urban:

- ✓ Always associated with an agricultural or an urban use of land, hedges and living fences should all be classified as Other Land, in the subcategory "Other Land *with TOF*" as long as they meet the thresholds.

- ✓ When they are planted and/or managed for agricultural or urban purposes, shelterbelts, windbreaks, tree lines and corridors of trees, should also be classified as Other Land, in the subcategory "Other Land *with TOF*" provided they meet the thresholds, because the underlying land-use is in that case predominantly agricultural or urban.

- ✓ When they are planted and/or managed for non-agricultural or non-urban purposes, shelterbelts, windbreaks, tree lines and corridors of trees should be classified either as Forest or as Other Land, in the subcategory "Other Land *with TOF*" as long as they meet the thresholds. It depends on combined [width x area x length] thresholds.

  - They should be classified as Forest when their area reaches more than 0.5 ha and their width is more than 20 m (in practice their length must thus be more than 25 m).

  - They should be classified as "Other Land *with TOF*" when their length is more than 25 m, and their width is between 3 and 20 m.

2.3.d. Agroforestry.

Most land supporting agroforestry systems is classified as "Other Land *with TOF*", because the land is used predominantly for agriculture. However, in a few cases it is classified as "Forest" because the predominant land-use is forest and not agriculture. There are many definitions of agroforestry, which is usually understood as "a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are always ecological and economical interactions between the different components" (Nair 1993). Somarriba (1992) complements this definition: "Agroforestry is a form of multiple cropping that satisfies three basic conditions: 1) There are at least two components of the cropping system that interact biologically; 2) at least one of the components is a woody perennial plant; and 3) at least two interacting species are managed to fulfill the objectives of the land manager." More recent definitions of agroforestry may be found in www.icraf.cgiar.org and www.aftaweb.org.

None of the definitions of agroforestry says anything about the predominant land-use of a given agroforestry system. Whether the land is predominantly used for agriculture or for forestry is a matter of balance between the agriculture and the forestry components of the agroforestry system. Most cases are clear-cut, with the balance bending toward agriculture (such as trees in cropfields or pastures, fruit orchards, coffee or cocoa plantations below a tree cover, pastures under coconut trees, cropfields surrounded by hedges), or toward forestry (such as in systems where livestock is allowed to graze in the undergrowth of a forest or timber tree plantation).

In a few cases of sequential agroforestry systems - such as many agroforests and Taungya systems- where a "mature" phase clearly dominated by trees succeeds an initial phase dominated by crops, the situation is more complex (Sinclair 1999, Wiersum 2004). In these cases, one should take into account the system's objectives and products to decide whether it belongs more to the forestry realm or to the agriculture realm.

Many agroforests belong to this group of sequential agroforestry systems with a mature phase characterized by a "forest" cover (Wiersum 1997, Michon & de Foresta 1999, Belcher et al. 2005). Although agroforests provide the same environmental services as a forest (Bhagwat et al. 2008), the land supporting these agroforests should be classified as "Other land *with TOF*" as long as it meets the conditions for OL*wTOF*, because farmers establish agroforests to generate income through the production of products belonging to the agriculture realm such as fruits and nuts, vegetables, rubber, cocoa, coffee, cinnamon, coconut, oil-palm, etc (Michon & de Foresta 1999). Sometimes items generally considered as non-wood forest products are also produced, such as the damar resin produced by Shorea javanica, a Dipterocarp species, in the damar agroforests planted and cultivated by farmers in the south of Sumatra, Indonesia (Michon et al. 2000). In any case, agricultural products are always present during the whole life of an agroforest, and the landowners' objective is never the establishment of a woodlot or a "forest", but the establishment of a mixed tree-crop plantation.

Taungya systems (Jordan et al. 1992) differ from agroforests mainly by their primary products (wood for timber or fiber) and by the landowners' objective: the establishment of a forestry plantation. They should thus be classified as "Forest". Taungya systems otherwise have many similarities with agroforests in their establishment and

their trajectory. In most Taungya systems, farmers grow crops during a few years only alongside young timber or fiber trees until the tree cover becomes dense enough to prevent crop growth. It then becomes a classic forestry plantation. The primary products are clearly forestry products, and the landowner's objective is the establishment of a forest plantation. This is why the explanatory note 9 in the definition of "Forest" (see above) says that "some agroforestry systems such as the Taungya system, where intercropping is reduced to the first 1-2 years of the establishment phase of crops are grown only during the first years of the forest rotation, should be classified as forest."

The "forestry" nature of the land under Taungya is obvious in typical cases where intercropping (concomitant occupancy of the same land by crops and tree species, Huxley 1983) is reduced to the first 1-2 years of the establishment phase of a 30-year rotation forestry plantation. This "forestry" nature is however less evident when (i) crops are selected for shade tolerance and other traits that enable them to be intercropped for a longer fraction of the total forestry rotation time, and (ii) tree species are selected for short-term rotations (e.g. for firewood, stakes, or for fibers), so that the intercrops share the land over a large fraction of – or even all - the forestry rotation. In cases where forestry and agriculture have the same weight, it seems that there is no objective way of classifying the system as "Forest" or as "Other Land *with TOF*".

Although a few agroforestry systems are classified as "Forest" (see the example of "Taungya" above), agroforestry is strongly linked to TOF in agricultural lands (TOF-AGRI), and to a lesser extent to TOF in urban lands (TOF-URB). The overlap between agroforestry and TOF is thus important to note since for all "Other Land *with TOF*" identified as under agroforestry, the rich agroforestry literature provides models, methods and assessments.

2.3.e. Agricultural or urban land-uses.

Both the "Forest" and the "Other Wooded Land" categories exclude land predominantly under agricultural or urban land use. It is thus of crucial importance, not only for identifying TOF and Other Land *with TOF*, but also for identifying Forest and Other Wooded Land, to know precisely how a piece of land may qualify as "predominantly under agricultural or urban land use" or not. The definitions of "Forest" and "Other Wooded Land" do not include any explanatory note on this expression, as if the meaning of this wording was obviously the same for everybody and as if it would be interpreted the same way everywhere in the world. As with the word "Forest", the words "Agriculture" and "Urban" in fact cover very different realities in different countries, which may lead to divergences in reporting.

✓ Agricultural land use. There is no internationally accepted definition of "agricultural land use." However, the FAO-FRA could adopt the definition used by the FAO Statistics Division (http://faostat.fao.org/) and include it in its reporting guidelines. The FAO Statistics Division defines "agriculture area" as "the sum of areas under:

- (a) Arable land - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for "Arable land" are not meant to indicate the amount of land that is potentially cultivable;
- (b) Permanent crops - land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under «forest»);
- (c) Permanent meadows and pastures - land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land)."

✓ Urban land use. Here again, there is no internationally accepted definition of "urban land use." And it seems that there is no consensus among countries even on the definition of "urban." The Demographic Yearbook 2005 published by the United Nations Statistics Division includes the definitions of "urban" used in 101 countries around the world. A rapid analysis shows that eight main criteria are used. They may be grouped in five main sets, listed here in decreasing order of importance:

- Population number (62 percent). A minimum population number is used in 60 national definitions and is by far the most common criterion for defining "urban." The thresholds are extremely variable and range from 200 inhabitants (for instance in Norway) to 50 000 (in Japan). In most countries the thresholds range from 1 000 to 5 000. A threshold population density is also sometimes used (present in 9 definitions: from 400 inh/km^2 in Canada, to 1 500 inh/km^2 in China), as well as a threshold number of dwellings (present in 2 definitions: 100 dwellings in Peru and 300 dwellings in Equatorial Guinea).

- Locality function (31 percent). To be an administrative center (often in relation to a large surrounding rural area) comes second in importance, although far behind the population number criterion. It is cited in 31 national definitions; being a center for commercial activities is also cited in 4 definitions.
- Official designation (27 percent). In 27 countries, governments officially designate which localities are urban.
- Relative importance of agriculture (20 percent). The low importance of agriculture is a criterion in 20 countries. It is sometimes quantified: for instance in Botswana "75 percent of the economic activity is non-agricultural" and in India "at least 75 percent of the adult male population employed in pursuits other than agriculture".
- Urban characteristics (17 percent). In 17 countries, a locality is defined as urban if it has urban characteristics, with a few countries qualifying some of these characteristics: for instance in Panama, these are "streets, water supply system, sewerage system and electric light".

This rapid analysis confirms the UN Statistics Division acknowledgement that "because of national differences in the characteristics that distinguish urban from rural areas, the distinction between the urban and the rural population is not yet amenable to a single definition that would apply to all countries."

Defining "urban" in the expression "urban land use" is important, but it is not sufficient: pieces of land with individual trees, with trees lining streets, canal or railways, with trees in private gardens, with trees on parking lots, etc, located in cities are obviously not "Forest" or "Other Wooded Land", and should thus be classified as "Other Land *with TOF*" when they meet the thresholds. But the ambiguity remains for pieces of land with trees located in hamlets, small villages, and built-up areas located in the countryside such as airports or camping grounds. The ambiguity also remains for large pieces of land supporting forest that are included in the territory of big cities: should they be classified as "Forest" because the local land use - land under the forest - is neither agricultural nor urban? Or should they be classified as "Other Land *with TOF*", because they are embedded into urban areas?

The above examples underscore the urgent need for clear guidelines on what should be considered an urban land use and what should not. This need is even greater for "urban" than for "agriculture", not only because there is less international consensus on what is urban than for agriculture and divergences between countries are more profound, but also because trees in cities are an increasingly important resource for the growing number of people living in cities worldwide.

As with agroforestry in the case of agricultural land, "urban forestry" as a scientific and technical discipline is dedicated to TOF in urban land. Despite the ambiguities in the exact meaning of "urban" land use, it is important to note that for all "Other Land *with TOF*" identified as predominantly urban, there is an ever-growing literature on urban forestry with models, methods and assessment.

The lack of precise and unambiguous definitions of "agricultural land use" and "urban land use" did not prevent the building of the rigorous framework based on mutually exclusive categories presented above in section 2.2. However, when it comes to practice, unambiguous definitions are needed in order to keep subjectivity out of the decision process that leads to

the classification of a piece of land with trees as "Forest", "Other Wooded Land", or "Other Land *with TOF*". Until now, countries have used their own definitions of "agricultural land use" and "urban land use" in their national reporting of Forest and Other Wooded Land to FAO-FRA – and most often these definitions are not cited in reports. This has added unknown levels of uncertainty regarding the relevance of national data both for comparisons between countries and also for use at higher geographic scales (region, world).

This report thus strongly recommends that clear and unambiguous definitions for "land predominantly under agricultural use" and "land under predominantly urban use", be prepared and included in the next FA0-FRA.

2.4. TOF and OLwTC

Following-up on the recommendations to include information on Trees Outside Forests into the FRA reporting process, beginning with the Global FRA 2005, the FAO/FRA has added a line in Table T1 "Extent of Forest and Other Wooded Land," asking countries to report the area of "Other Land with Tree Cover" (OLwTC), a subcategory of "Other Land", defined as follows (FAO 2010b):

Other Land With Tree Cover (OLwTC) – subcategory of Other Land:

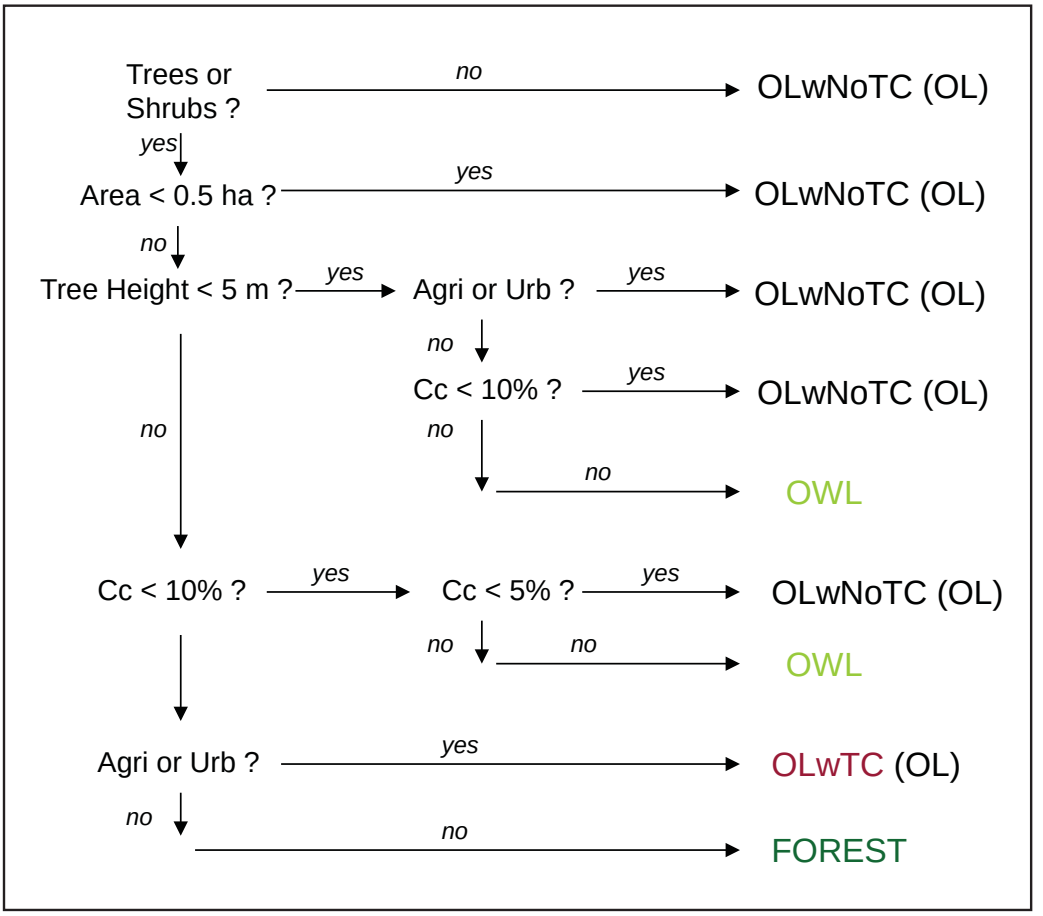
Land classified as Other land, spanning more than 0.5 ha with a canopy cover of more than 10 percent of trees able to reach a height of 5 m at maturity.

Explanatory notes:

1. The difference between Forest and Other land with tree cover is the land-use criteria.
2. Includes groups of trees and scattered trees in agricultural landscapes, parks, gardens and around buildings, provided that area, height and canopy cover criteria are met.
3. Includes tree stands in agricultural production systems, for example in fruit-tree plantations and agroforestry systems when crops are grown under tree cover. Also includes tree plantations established mainly for purposes other than wood, such as oil-palm plantations.
4. Excludes scattered trees with a canopy cover less than 10 percent, small groups of trees covering less than 0.5 ha and tree lines less than 20 m wide.

A decision tree algorithm for distinguishing Other Land With Tree Cover from Forest, Other Wooded Land and Other Land With No Tree Cover, is proposed in Figure 4. It uses the same criteria as those used in Figure 3, except those related to linear tree formations: whatever the tree spatial pattern, what is important here, provided all other thresholds are met, is the area (above 0.5 ha: Forest, Other Wooded Land or Other Land with Tree Cover; below 0,5 ha: Other Land With No Tree Cover).

Figure 4: A decision tree algorithm for OLWTC, Forest, OWL and Other Land With no Tree Cover



Five (minimal and sufficient) decision criteria were deducted from the FAO-FRA definitions and used to construct the decision tree algorithm for classifying land as

- Forest (FOREST).
- Other Wooded Land (OWL).
- Other Land with Tree Cover (OLWTC).
- Other Land with No Tree Cover (OLWNoTC).

The five decision criteria (in parentheses the levels for each criterion) were:
1 = Presence of Trees or/and Shrubs on the land (yes/no).
2 = Trees or/and Shrubs patch area (threshold: 0.5 ha).
3 = Trees or Shrubs height at maturity (threshold: 5 m).
4 = Land Use (Urban or Agriculture/Other).
5 = Trees or Shrubs canopy cover (thresholds: 5 % for Trees, 10% for Shrubs and small trees).

OLWTC has the same thresholds than "Forest" in terms of plant height (≥5 m), canopy cover (≥10 percent) and area (≥0.5 ha). OLWTC is thus a subcategory of Other Land supporting enough trees for being classified as Forest on the criteria of area, canopy cover and tree height. OLWTC is the equivalent of the "Forest" category in the TOF realm (figure 4a and 4b). How does OLWTC fit with the different TOF subsets presented above in section 2.2.c resulting from the definitions of Forest and Other Wooded Land?

It is clear that OLWTC excludes the *Non Agricultural/Non Urban* set and its four subsets. This is underlined by explanatory note 4, which "excludes scattered trees with a canopy cover less than 10 percent" (= subsets 3 and 4 of the TOF typology, section 2.2.c), "small groups of trees covering less than 0.5 ha" (= subset 1 of the TOF typology), "and tree lines less than 20 m wide" (= subset 2 of the TOF typology).

A direct result of these exclusions is that OLWTC only concerns part of agricultural land (set 1: TOF on Agricultural Land – AGRI), and part of urban land (set 2: TOF on Urban Land – URB). Within each of these 2 TOF sets, OLWTC represents the part that meets the same thresholds as "Forest" (see Figure 5a and 5b). This is underscored by explanatory note 1 above, which states that "the difference between Forest and OLWTC is the land-use criteria."

It is important to note that OLWTC is fully embedded into Other Land *with TOF*, but that Other Land *with TOF* is wider than OLWTC (Figure 5b).

Figure 5a: Land not predominantly under agricultural or urban use Position of Forest, Other Wooded Land and Other Land, when land is ≥ 0.5 ha.

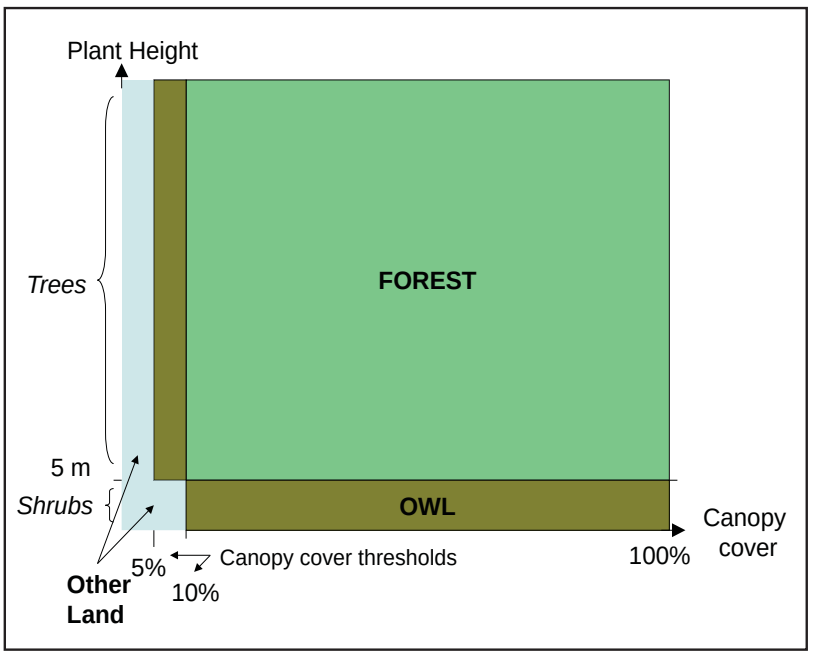
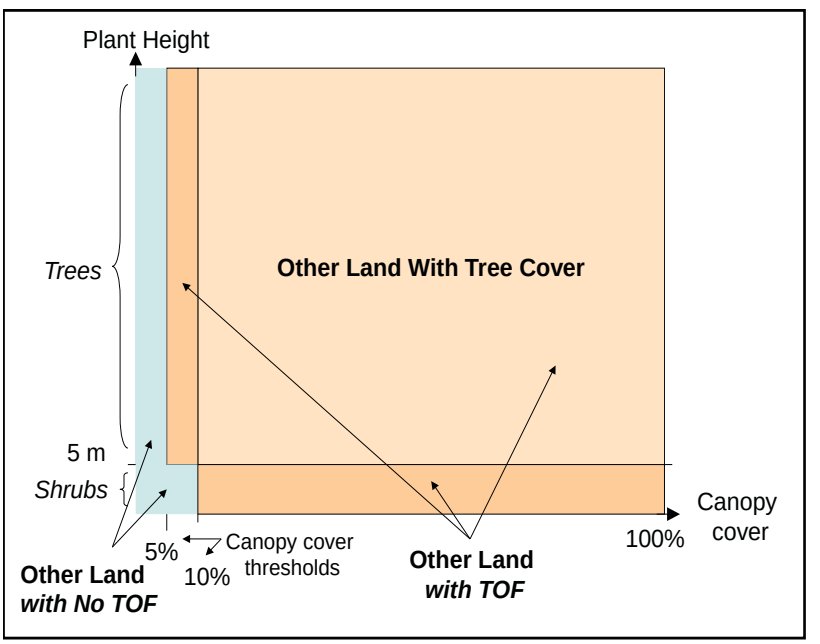


Figure 5b: Land predominantly under agricultural or urban use Position of Other Land with Tree Cover within Other Land *with TOF* when land is ≥ 0.5 ha.



Building upon OLWTC to assess OL*wTOF*?

OLWTC is a subdivision of the subcategory OL*wTOF* based on land cover and land-use criteria. This subdivision introduces a new option for classifying the complement of OLWTC in the TOF realm on a pure land cover basis for at least two subsets. Once OLWTC had been circumscribed, the rest of OL*wTOF*, may be subdivided into four mutually exclusive subsets:

1. Small tree stands or groups (0.05 ha≤area<0.5 ha), with a canopy cover ≥5 percent if only trees and ≥10 percent in case of a combined cover of trees and shrubs. Whether located on agricultural land, urban land or non-agricultural/non-urban land, such small tree stands are classified as Other Land *with TOF* but are not included into OLwTC.
2. Linear tree formations more than 25 m long, narrow (3 m ≤width <20 m), irrespective of area, plant height and canopy cover level. Whether located on agricultural land, urban land or non-agricultural/non-urban land, narrow linear tree formations are classified as Other Land *with TOF* but are not included into OLwTC.
3. Large stands (area ≥ 0.5 ha), shrubs or small trees (height <5 m) with a canopy cover level ≥10 percent, located on agricultural land or urban land. Such stands are classified as Other Land *with TOF* but are not included into OLWTC.
4. Large stands (area ≥ 0.5 ha), trees (height ≥ 5 m) with low canopy cover level (between 5 and 10 percent), located on agricultural land or urban land. Such stands are classified as Other Land *with TOF* but are not included into OLwTC.

The first two above subsets may be translated into two major tree spatial organization patterns - small and relatively dense tree groups, and narrow tree lines -, that may be found on agricultural land, urban land or non-agricultural/non-urban land.The two other sub-categories – large stands with a canopy cover of shrubs ≥10 percent, and large stands with scattered trees (canopy cover between 5 and 10 percent) – should be classified differently according to the land-use: as OWL when the land is not predominantly under agricultural or urban land, and as OL*wTOF* when the land-use is predominantly agricultural or urban. For assessing the extent of TOF by high resolution remote-sensing imagery, this classification based on the spatial structure of trees may be of high interest.

2.5. Conclusions

This chapter used an analysis of the accepted definitions needed to circumscribe the TOF realm as a basis for proposing that Other Land be subdivided into two mutually exclusive sub-categories, based on the presence of TOF at certain threshold levels: Other Land *with No TOF* and Other Land *with TOF*. An operational definition of these two sub-categories is given.

The analysis also provided the basis for a TOF typology including three major TOF sets (Figure 6):

1. TOF on land predominantly under agricultural land use are classified as TOF-AGRI ; part of TOF-AGRI is included in Other Land *with TOF* (OL*wTOF-AGRI*), when the canopy cover and area thresholds are met. OL*wTOF-AGRI* includes all lands predominantly under an agricultural land use with trees and/or shrubs, whatever their spatial pattern (in line, in stands, scattered), provided that the area is ≥ 0.05 ha, the canopy cover is ≥ 5 percent if only trees are present, or ≥ 10 percent in case of combined trees and shrubs, the width ≥ 3 m and the length ≥ 25 m for linear tree formations.

   If the trees are ≥ 5 m high, with a tree canopy cover ≥ 10 percent, the width ≥ 20 m and the area is ≥ 0.5 ha, the land is also classified as Other Land with Tree Cover (OLWTC).

2. TOF on land predominantly under urban land use are classified as TOF-URB; part of TOF-URB is included in Other Land *with TOF* (OL*wTOF-URB*), when the canopy cover and area thresholds are met. OL*wTOF-URB* includes all lands predominantly under an urban use with trees and/or shrubs whatever their spatial pattern (in line, in stands, scattered), provided that the area is ≥ 0.05 ha, the canopy cover is ≥ 5 percent if only trees are present, or ≥ 10 percent in case of combined trees and shrubs, the width ≥ 3 m and the length ≥ 25 m m in case of linear tree formations.

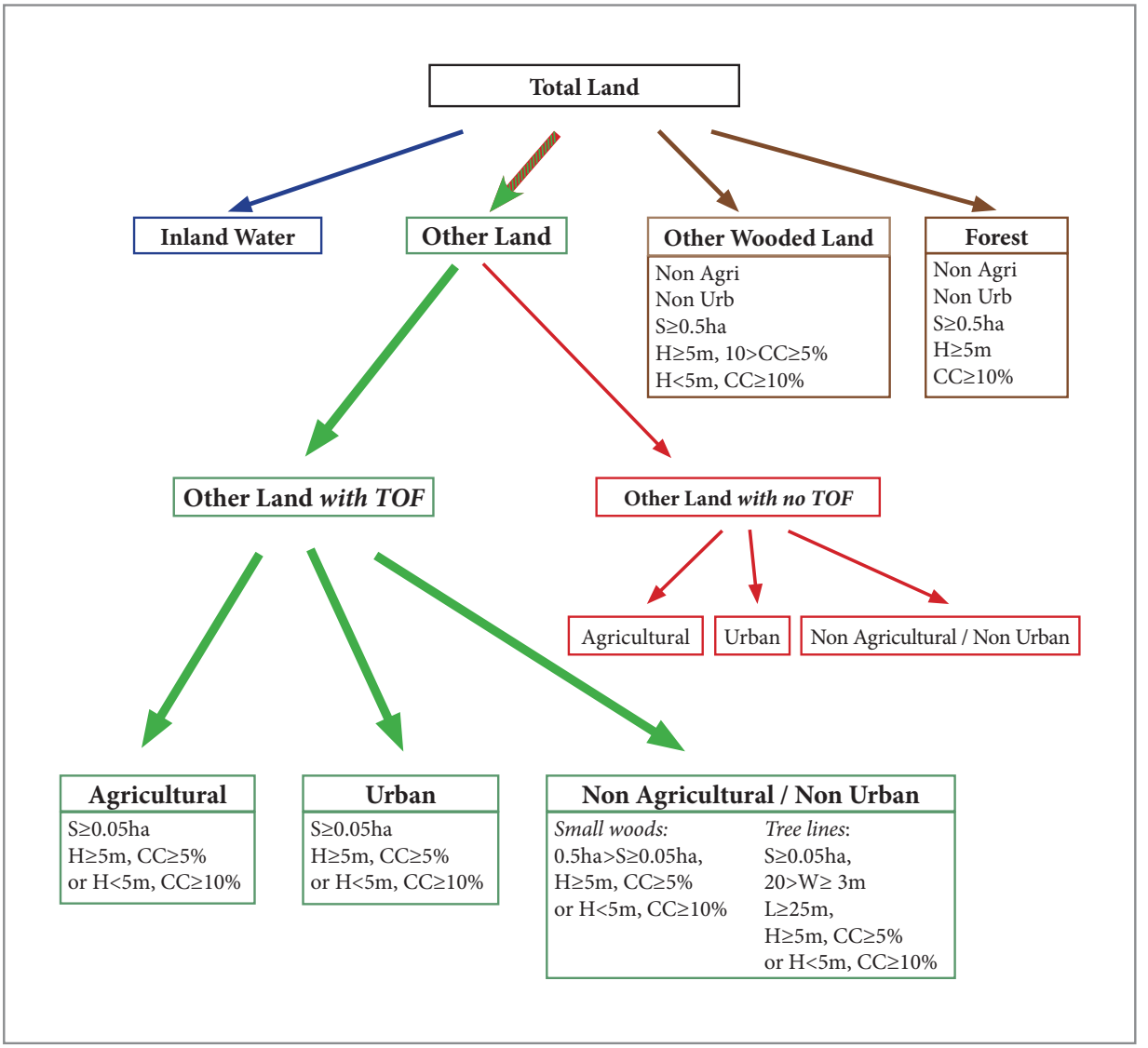
   If the trees are ≥ 5m high, with a tree canopy cover ≥ 10 percent, the width ≥ 20 m and the area is ≥ 0.5 ha, the land is also classified as Other Land with Tree Cover (OLWTC).

3. TOF on land not predominantly under agriculture or urban land use are classified as TOF-NON A/U. Part of TOF-NON A/U is included in Other Land *with TOF* (OL*wTOF- NON A/U*), when the thresholds are met. This is the case for the two following subsets:

   OL*wTOF- NON A/U* - Subset 1: small tree stands (0.05 ≤ area <0.5 ha) with canopy cover ≥ 5 percent if trees are present, or ≥ 10 percent in case of combined trees and shrubs.

   OL*wTOF- NON A/U* - Subset 2: narrow linear tree formations, (3 m ≤ width < 20 m), with length ≥ 25 m, and canopy cover ≥ 5 percent if trees are present, or ≥ 10 percent in case of combined trees and shrubs.

Figure 6: The position of Other Land *with TOF* and its sets within the proposed land classification framework for Other Land



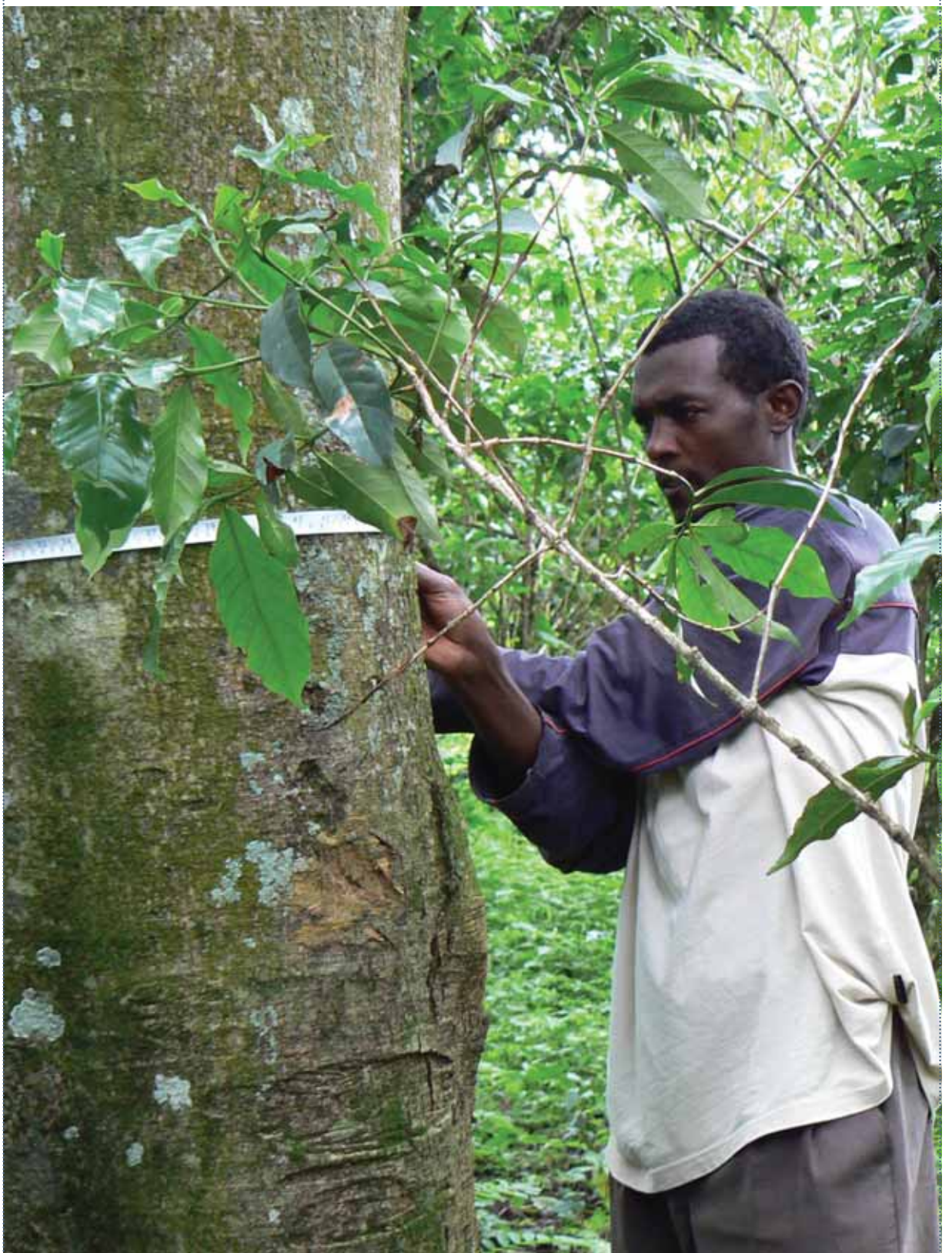
The rigorous framework deriving from this analysis is constrained by a few remaining ambiguities in the terms used for the definition of Forest and Other Wooded Land. In some situations, these ambiguities introduce subjectivity into classifying a piece of land with trees into Forest, Other Wooded Land, or Other Land *with TOF*. Recommendations for removing these ambiguities have been formulated.

The position in the TOF realm of Other Land with Tree Cover, a category recently introduced by FAO-FRA to start to account for TOF, has also been clarified, and its interest, as opening up a new option for classifying the remnants of the Other Land *with TOF* subcategory on an almost pure land-cover basis, underlined.

To conclude, it is important to stress that TOF and Land with TOF have been understood here in the land classification frame of reference of the FAO-FRA, which has a strong focus on forest. The three major TOF sets identified in this chapter correspond to a large variety of stakeholders: farmers, pastoralists and institutions linked to agriculture and rural development; people living in settlements and cities, institutions linked to urban management and development; environmental organizations, rural and urban planning institutions, etc. These extremely diversified stakeholders have objectives and needs that are often very different from those of foresters.

Trees outside Forests provide an opportunity to bridge the divide that sometimes separates foresters from other stakeholders (Dove 1992, 2005, Sood & Mitchell 2009). TOF and the TOF realm, although they are here analyzed through an international forestry-oriented framework, could help in building that bridge.

3. Review of TOF assessments



3.1. Introduction

This chapter reviews the various types of inventory and assessment that may provide data on TOF (hereafter called "TOF assessments" for simplification). Inventory is the process of collecting quantitative and qualitative information on a given resource, while assessment is the process of putting data in context and assigning values to the resource (Kleinn, 2000). The focus is on TOF assessments at scales that are relevant to national policy-makers and the global community: region, country and large area. No attempt was made to collect and analyze case studies involving TOF assessments in small areas. A number of small-scale studies exist, that cover a wide spectrum of TOF systems and a large number of geographical situations, providing a bulk of useful and valuable information on TOF, their use and their management. Despite their interest, these small-scale studies are not presented here because their results and methodologies cannot easily be extrapolated to larger scales.

Various methods and tools can be used to provide relevant information on TOF; three main groups are:

- ✓ Remote sensing and the analysis of aerial photographs and satellite images, combined with ground checking, may provide information on the extent, localization and spatial organization of TOF. Impressive technological progress has made remote sensing an essential tool for measuring these parameters and their change with time.

- ✓ Field inventories that combine sample plots with various tree measurements for information on the tree resource itself: biophysical parameters such as tree density, average height and diameter, volume of timber, tree health, tree species composition and diversity, etc. Provided the sampling scheme is adapted to the area covered, valid statistic estimates of the tree resource over the whole area can be derived, such as the number of trees, the stocking volume, the carbon stock, etc. When combined with interviews, field inventories may also provide information on the use of the trees, their management and their socio-economic value.

- ✓ Survey questionnaires may provide information on various aspects of the TOF resource especially on land used for tree crops in agriculture, but also on urban land. Surveys usually involve interviews with, or questionnaires sent to, local TOF managers (farmers, city staff, etc.), and the information is usually limited to the extent of TOF, various aspects of their production (agricultural land) or their social and environmental services (urban land), and various aspects of their management.

The three groups of methods briefly described above may be used independently or jointly in TOF assessments. Each group provides specific information, different from the others. Assessments collected and analyzed in this chapter consist of these three groups, allowing comparisons.

The information from collected assessments was compiled, analysed and synthesised with the ultimate aim of drawing feasible technical and methodological options for better TOF assessments. In the following, the terms "Forest" and "Other Wooded Land" exclusively refer to their current FAO definitions as presented

in chapter 2, unless otherwise stated. Similarly, the term "TOF" exclusively refers to the proposed definition formulated in chapter 2.

The chapter is organized in 3 sections: section 1 (The process) clarifies the process of collecting, analysing and comparing the assessments ; section 2 (TOF Assessments) deals with the review itself, clarifying the pros and cons of each type of assessment for TOF; section 3 highlights the main conclusions (Towards developing options for TOF assessment: major observations).

3.2. The process

Chapter 2 made clear that TOF and land with TOF may be divided into three major subsets: TOF on land used for agriculture, TOF on land used for settlement and TOF on land not used for agriculture nor for settlement. An important consequence of the presence of TOF in these three major land-use types is the fragmentation of TOF issues among the institutions dealing with various sectors including inter alia agriculture, land use and city planning, environment, economy, development, and forestry. This fragmentation is in itself a problem when assessing TOF as a whole because it means that data on TOF subsets may in theory be generated, analysed and held independently by a wide range of institutions. This is true at sub-national and national levels where different ministries (or different agencies from the same ministry) may have different TOF subsets in their mandate. This is true also at the global level where the various TOF subsets fall under the mandates of numerous UN agencies such as FAO, UNEP, and UNSD, or of various departments inside one agency. Despite this fragmentation, at the global level FAO should be the reference for national TOF data as its mandate includes the collection of statistical data on renewable natural resources related to food and agriculture.

3.2.a. Screening and collecting phase

FAO documents and statistics provided the starting point of the screening phase, pointing towards countries where quantitative information on TOF was potentially available, meaning that inventories or assessments were potentially available for these countries.

The recent FAO-FRA 2010 country reports were used to identify countries having reported the OLwTC category ("Other Land with Tree Cover") in Table 1 of their national report ("Extent of Forest and Other Wooded Land"). OLwTC provides information on the spatial importance of relatively large patches (> 0.5 ha) of agricultural and urban land where TOF canopy cover is more than 10 percent (see chapter 2). Although OLwTC does not account for all TOF, the hypothesis was that countries that reported an area as OLwTC would have documents available on large-area TOF assessments. FAOSTAT database was used to identify countries with reportedly large areas of tree crops (that make up part of the agricultural TOF set), whether these countries reported their tree-crop areas in the OLwTC line of the FAO-FRA 2010 report or not. Once countries potentially having TOF assessments were identified, a search for documents pertaining to these assessments was carried out, by contacting FAO national correspondents and by Internet searches.

In parallel to the analysis of the FRA 2010 country reports and the FAOSTAT database, the researchers sent a letter to FAO-FRA national correspondents in 170 countries, requesting their assistance in identifying relevant national assessment documents, originating from the forestry sector or any other sector. The letter included a list of the main tree systems that might include TOF (such as perennial tree crop plantations, hedges and windbreaks, agroforests, parklands). Responses confirmed the interest in TOF expressed by countries that had noted OLwTC in FRA reports, and allowed the integration of a few other countries in the review.

3.2.b. Pre-analysis phase

Through the screening and collection phase, a number of documents from various sources were organized in two main groups. The first group consists of all the assessments (1 global, 1 regional, 33 national and 3 sub-national), that could provide information on one or another TOF set. The assessments included in this review cover the main methods in use and the various TOF sets. They also cover a very large range of environmental and socio-economic conditions, as they have been carried out in countries belonging to almost all the major world regions (see Table 3).

Table 3: World distribution of country case studies (national and sub-national assessments)

World Regions	Countries selected for case study
Eastern and Southern Africa	Zambia
Northern Africa	Morocco
Western and Central Africa	Cameroon, Senegal
East Asia	China
South and Southeast Asia	Bangladesh, India, Philippines
Europe	France, Italy, Norway, Slovenia, Sweden, United Kingdom
Central America	Nicaragua
North America	Canada, USA
South America	Uruguay
Oceania	New Zealand

The second group relates to a few international supporting programmes developed by FAO and partners, programmes that may help in providing information on TOF, although that is not usually a primary objective:

- ✓ LADA: The Land Degradation Assessment in Drylands programme.
- ✓ LCCS: The Land Cover Classification System programme,
- ✓ NFMA: The National Forest Monitoring and Assessment programme
- ✓ WISDOM: The Woodfuel Integrated Supply/Demand Overview Mapping,

The reviewed documents are neither a complete collection of all relevant assessments nor a random sampling of the existing relevant assessments. However, they constitute the largest and most diverse range of assessments related to TOF possible, and they cover all the major assessment categories.

3.2.c. Analysis phase

Each assessment and each supporting programme was systematically analysed for the following points:

- ✓ Objective(s) of the assessment or programme;
- ✓ Institutions involved and coordinating institution(s);
- ✓ Scale (global, regional, national, sub-national);
- ✓ Duration and periodicity (for assessments);
- ✓ Methodology used;
- ✓ Variables recorded related to TOF;
- ✓ Identification of categories that may include TOF;
- ✓ TOF subsets included in the coverage;
- ✓ Main kind of results regarding TOF provided or that may be provided;
- ✓ Main results (for assessments).

Synthetic profile sheets were made for each assessment (Part 2a) and for each supporting programme (Part 2b). National assessments have been organized by country, because in most countries, complementary data on TOF may be gathered from different national inventories, due either to the land-use dispersal of TOF or to differences in the targeted variables. The profile sheets were used as a basis for the comparative analysis of the assessments. All points that were unclear in the available documents were clarified by experts working in the supporting programmes for the global and regional assessments, and by national experts for the countries. Once completed, each profile sheet was as far as possible sent for checking and validation to programme experts or to the relevant contact-person(s) in the countries. This process was considered extremely important: it helped to build a common understanding among specialists who may have very different cultural, technical and conceptual perceptions; it ensured the reliability of the information summarised in the profile sheets; and it allowed the comparative analysis of the selected assessments to be carried out on a sound basis.

3.3.TOF assessments

This section reviews the large area TOF assessments collected as well as the supporting programmes that provide or may provide information on TOF. The synthetic profile sheets synthesizing the information on each assessment and supporting programme are located in part 2 of this report for practical reasons. These profiles are however constantly referred to in this section and are conceived to be read in conjunction with this section.
The direct consequence of the heterogeneity of TOF as a category is the difficulty in developing a comprehensive assessment that would cover all the existing TOF sets and subsets. Indeed, no such assessment could be found in our review and one might question the need to develop such an assessment versus developing selective assessments focusing on specific TOF categories.

Some countries did implement assessments specifically targeted toward one TOF set or another, or toward part of a TOF set (see 3.3.a. below: Assessments focusing on specific TOF sets). Many countries have conducted assessments that provide or may provide information, albeit partial, on at least some TOF sets. Information on the area and location of some TOF sets can be extracted from land-cover and land-use assessments, provided they include such TOF sets as specific land-cover/land-use categories (see 3.3.b. below: Land-cover and land-use assessments including TOF subsets). Biophysical and sometimes socio-economic information on some TOF sets can also usually be extracted from National Forest Inventories, especially when they include sampling in non-forest areas (see 3.3.c. below: National Forest Inventories). The distribution, among these three main groups, of the assessments reviewed in this report, is presented in table 4.

Table 4: Distribution of the assessments between land-use/land-cover (LU/LC) type, national forest inventory (NFI) type, and TOF specific assessments.

Assessment	Type of assessment					
	LU/LC type	NFI type	TOF specific	TOF subset(s) covered or specifically targeted by the assessment		
				AGRI	URB	OTHER
Europe - CORINE LAND COVER	X			X	X	X
India FC/TC Assessment	X			X	X	X
Morocco Globcover LC-mapping 2008	X			X	X	X
New Zealand LCDB2	X			X	X	X
New Zealand LUCAS	X			X	X	X
Senegal Land-Cover mapping	X			X	X	X
US NRI	X			X	X	X
Sweden NILS	X			X	X	X
Bangladesh NFTA		X		X	X	X
Cameroon NFRA		X		X	X	X
Canada NFI		X		X	X	X
China NFI		X		X	X	X
Nicaragua NFI		X		X	X	X
Philippines NFTRA		X		X	X	X
Sweden NFI		X		X	X	X
US FIA		X		X	X	X
Zambia ILUA		X		X	X	X
Morocco NFI		X		X	O	X
Norway NFI		X		X	O	X
Senegal - PROGEDE		X		X	O	X
Slovenia FFECS		X		X	O	X
Uruguay NFI		X		X	O	X
US Great Plain States - Non Forest			X	X	X	X
India TOF inventory			X	X	X	X
Slovenia - WISDOM			X	X	X	X
Italy - Hedgerows and small woods assessment*			X	X	X	X
France - Linear formations*			X	X	O	X
UK - Countryside Survey*			X	X	O	X
UK - Small Woods			X	X	O	X
Global - Trees on Farm			X	X	O	O
Morocco Citrus Census			X	X	O	O
New Zealand APS			X	X	O	O
UK - Fruit and Orchard Survey			X	X	O	O
Uruguay GCA			X	X	O	O
UK - Trees in Towns II			X	O	X	O
Canada - Toronto UTCA			X	O	X	O
US - Urban Forestry			X	O	X	O
Sweden - Urban Forestry			X	O	X	O

Note: * means that the assessment is compiled in the «Inventories of Linear Tree Formations» profile sheet

3.3.a. Assessments focusing on specific TOF categories

The only global-scale assessment related to TOF currently available focuses on agroforestry (the "Trees on Farm" Study – Zomer et al. 2009). All other large-area assessments in this group have been conducted at national and sub-national scale, focusing on trees in part of the non-forest land –with forest land being defined according to national definition, which is very often different from FAO definition (Lund 2002). Non-forest land is usually subdivided into rural areas and urban areas with assessments that are specific to each of these subdivisions and that use different methodologies. In addition to these, some assessments deal with more specific TOF categories, such as commercial non-forest tree crops (all of them TOF), which are included in national agricultural production surveys conducted by many countries, but also "working trees" (USA), small woodlands and trees (UK) or hedges (with examples from France, Italy and the UK).

Trees on Farm - Global extent of agroforestry

The main purpose of the "Trees on farm" study (Zomer et al. 2009) was to quantify and map the extent of agroforestry at the global level, considering only the land used for agriculture, thus excluding land under urban use and land under forest (see Part 2b: Trees on Farm TOF profile). Using remote-sensing derived global datasets at a 1 km resolution, the study produced a series of maps of the tree-cover density on agricultural land. Although results should be considered as rough estimates because of the low resolution of the datasets, they very importantly show that agroforestry is a significant feature of agriculture in all regions, and that at a global level, more than 10 million km^2 (46 percent of the land classified as agriculture land in the global datasets) have more than 10 percent tree cover. No field sampling was undertaken during the study, and consequently its results are limited to spatial information, excluding any biophysical or compositional information.

Assessment of rural TOF

The only nation-wide integrated assessment focusing explicitly on TOF in rural areas has been conducted in India (see Part 2a: India TOF profile). Implemented by the Forest Survey of India as part of the periodic Indian National Forest Inventory, the assessment includes the analysis of high-resolution satellite images and field inventories in randomly selected sampling sites. Rural TOF are subdivided into 3 classes based on their geometrical shape (block: compact group of trees > 0.1 ha, linear tree formation and scattered trees) and different field sampling strategies are developed for each class, according to their respective characteristics. Spatial, biophysical and socio-economic attributes recorded through field sampling are numerous and contribute to the building of a reliable and accurate information base on TOF in rural areas at a national scale. One restriction, however, is that a minor part of the land supporting rural TOF is not taken into account in this assessment because it is classified as "forest" due to uncertainty in locating the exact boundaries of the recorded forest areas.

Assessments of urban TOF

Trees in an urban environment are most often assessed by municipalities at the city or town scale. Many cities in the world have their own urban forestry assessment and monitoring programme (see Part 2a: Canada TOF profile, the example of Toronto). Four countries (India, Sweden, the United Kingdom and the United States of America)

have conducted integrated assessments of urban trees at the regional or national scale.

In the USA (see Part 2a: USA TOF profile), "Forest on the Edge" is a long-term program of the US Forest Service devoted to urban forestry. The program released a report including the main results of a country-wide assessment of urban forests, defined as all publicly and privately owned trees within an urban area, including trees along streets and in backyards, as well as stands of remnant forests (Nowak et al. 2010). Using high-resolution, remote-sensing derived data combined with maps of urban areas, the assessment did not include any field measurement and exclusively focused on tree canopy cover and tree density in the urban areas of each county (local jurisdiction).

In India, the "TOF urban" assessment is part of the periodic National Forest Inventory and records different spatial, biophysical and socio-economic attributes in randomly selected "urban block" samples, with the number of field samples increasing with the number of blocks in a city (see Part 2a: India TOF profile). As with the "TOF rural" inventory, the Indian "TOF urban" inventory results in a sound and accurate information base on TOF in urban areas at the national scale.

In UK, the Trees in Town II project (2004-2008) involved local, regional and national organizations and institutions from various sectors under the coordination of the Department for Communities and Local Government. It aimed at providing up-to-date information on England's urban tree stock and urban tree management (see Part 2a: UK TOF profile). The assessment was based on a preliminary stratification (region, town size, land-use type) followed by the random selection of 590 (200 x 200 m) field samples distributed over all the strata. It included a survey questionnaire sent to all local authorities in charge of city trees. A combination of high-resolution, remote-sensing derived data and measurements of spatial, biophysical, managerial and socio-economic attributes in each field sample further ensured high-quality qualitative and quantitative results. The Trees in Town project was partly reproduced in Sweden where a survey of urban forestry was conducted in 2006, based on survey questionnaires sent to local authorities (see part 2a: Sweden TOF profile).

Agricultural production surveys

All countries need statistically relevant data on their agricultural production. Agricultural services in many countries are conducting more or less periodic and detailed surveys on agricultural variables such as the areas under each major commercial crop, the annual production, the number of farmers, the use of fertilizers and pesticides, etc. These surveys usually include inter alia the collection of data on the country major commercial tree crops. Because all tree-crop plantations are TOF (they are made up of trees on land that is used primarily for agriculture), these surveys are an important source of information on TOF. The "Fruit and Orchard survey" in UK (see Part 2a: UK TOF profile) and the "Agriculture Production Survey" in New Zealand (see Part 2a: New Zealand TOF profile) are

two examples of such surveys, based on questionnaires sent to tree-crop farmers previously identified through periodic population census. In other countries such as in Morocco with the "National Citrus Census" and in Uruguay with the "General Census of Agriculture", questionnaires are completed by agents of the agriculture services through direct interviews with the farmers. These surveys generally do not provide information on all tree-crop plantations: in New Zealand for instance, the questionnaire is sent to tree-crop farmers having an income above a certain threshold amount; in UK, the questionnaire is sent to farmers having more than 1 ha in tree-crop plantations. With these restrictions in mind, agriculture production surveys provide at least a lower estimate of the country area under various tree-crops[1]. In the best cases they also provide biophysical and socio-economic data that allow estimates of carbon sinks due to tree crops or their economic value at national scale.

The "Working Trees" study (2008) covered 10 states in the North Central part of the USA. It is a good example of a territory-wide assessment focusing on agroforestry trees in the agricultural landscape (see Part 2a: USA TOF profile). This assessment did not involve new sampling, but built on a comparative analysis of the extent of "working trees" as estimated through data produced by the US Forest Inventory and Analysis (FIA) programme (see Part 2a: USA TOF profile) and through data from the MODIS Vegetation Continuous Field (VCF) global dataset based on low-resolution satellite images (500 m). Among other more specific results, the study showed that the national FIA programme underestimates the importance of some working trees categories such as narrow windbreaks and shelterbelts, which are not included in its inventories.

Other specific TOF category assessments

Three other types of large-area assessment have been found that focus on specific TOF categories: one sub-national survey focusing on "working trees" (used here partly as a synonym for "agroforestry trees") in the USA, one national survey focusing on small woodlands and trees in the UK and a set of sub-national and national surveys focusing on linear tree formations. In addition to these assessments, two international supporting programmes (WISDOM and LADA) should be mentioned here as they focus on specific categories (the wood for fuel in WISDOM, and the tree resource in degraded land for LADA) that cross-cut all TOF subsets as defined in Chapter 2.

1 The estimate of the extent of the major tree crops in a country is also commonly produced by national land-use/land-cover assessments (see 3.3.a below). Another method commonly used to estimate the area covered by a given tree crop is to extrapolate the average yield to the total country production.

The "Survey of Small Woodland and Trees" in the UK is a periodic survey involving various organizations and institutions under the coordination of the Forestry Commission. It focuses on the assessment of the tree resources –excluding orchards and urban trees- in individual areas smaller than 2 ha (see Part 2a; UK TOF profile). Four categories are identified: "Small wood" (woodland > 0.1 and <2 ha); "Groups" (group of 2 or more trees with an area < 0.1 ha); "Linear feature", further subdivided into narrow (< 16m wide) and wide (> 16m wide) linear features; and "Individual trees." Various spatial, biophysical and managerial attributes are measured on each of these four categories through the analysis of high resolution remote-sensing based datasets and through measurements in a large number of 250 x 250 m sample plots selected randomly and representing 1 percent of the inland area and 1 percent of the coastal area. No category can be fully assimilated to a TOF category, except the "narrow linear feature" category. Information on three TOF subsets may however be extracted from the original data: narrow linear tree formations, by adding part of the "Wide linear Feature" category (less than 20 m width) to the already mentioned "narrow linear feature category"; woodlands smaller than 0.5 ha are extractable from the "Small wood" category; and areas with scattered trees less than 5 percent cover are extractable through a search for "groups" and "isolated trees" on the remote-sensing datasets.

Three assessments carried out at national scale in European countries specifically targeted linear tree formations. Hedgerows in particular were once very abundant in pasture areas (Burel & Baudry 1990, Deckers et al. 2005, Guillerme et al. 2009, Sklenicka et al. 2009, Plieninger 2012). They progressively disappeared since the 1960's but recent studies highlighted their environmental benefits (e.g. Boughey et al 2011, Paletto & Chincarini 2012), and new policies now support their plantation and maintenance for sustaining biodiversity (http://ec.europa.eu/agriculture/envir/measures/) and for adapting farms to climate change (http://ec.europa.eu/agriculture/climate-change/). The three following assessments have been made in this context (see Part 2a: Linear Tree Formations TOF Assessment Profile).

In France, the "Inventory of Linear Tree Formations," implemented since 2008 by the French National Forest Inventory, has the aim of providing up-to-date information on national tree stock outside forests. "Linear Tree Formations" are here defined as tree lines more than 25 m long and less than 20 m wide. The assessment relies on the systematic 1 km x 1 km grid used by the French NFI and on high-resolution remote-sensing datasets. On remote sensing plots that are selected each year for sampling, a 1-km long, randomly oriented transect is drawn in each non-forest area and linear tree formations intersecting the transect are counted. A sub-sample of these tree lines are then selected for detailed field measurements to provide a reliable and accurate picture at the country scale of the spatial, biophysical and management status of linear tree formations.

In Italy, an assessment of narrow linear tree formations and woodlots was undertaken by the Forest Monitoring and Planning Research Unit of the Agriculture Research Council, in the framework of the National Inventory of Forests and Carbon Sinks (INFC) that began in 2002. During the photo-interpretation phase, all inventory sampling points located outside forests were classified with reference to the two TOF subsets N1 (small woods) and N2 (narrow linear tree formations). Italy used the same definitions as FAO, and the assessed linear tree formations thus strictly correspond to TOF subset N2. The INFC also relies on a 1 km x 1 km grid and on high-resolution remote-sensing datasets, with a slightly different sampling protocol than the NFI in France, and linear tree formations are inventoried in full in each remote-sensing sampling plot. Detailed field measurements were not integrated in the assessment, although a field sampling protocol has been tested in one province.

In the United Kingdom, the Countryside Survey is a periodic country-wide assessment managed by the Centre for Ecology and Hydrology, one of the research centers of the Natural Environment Research Council. It aims at providing up to date information on natural resources in the UK countryside, including a Land Cover map with detailed land cover at a "field by field" scale. The assessment comprises a Field Survey, including inter alia an inventory of linear tree formations, based on a set of 1 x 1 km sample plots distributed all over the country and randomly selected within each of the major habitat types of the country. Although no maximal width threshold is included in the definitions of the assessed linear tree formations, they are assumed to broadly correspond to TOF subset N2.

The Woodfuel Integrated Supply/ Demand Overview Mapping (WISDOM) is an international supporting programme that was initiated in 2003 in the context of FAO country assistance, through collaboration between the FAO Wood Energy Program and the Institute of Ecology of the National University of Mexico (see Part 2b: WISDOM TOF profile). It developed a methodology applicable at various scales (city, country, region) to assess and map the supply and demand of fuel wood as a tool for wood-energy planning and policy. In any given WISDOM project, priority goes to the use of existing sources of information on trees in forest lands and in non-forest lands to assessing the fuel wood supply potential. Data on trees in forest lands are usually available, but data on trees in non-forest lands are often not. Special assessments thus have to be carried out, as in the cases of Rwanda and Slovenia (see Part 2a: Slovenia TOF profile). In Slovenia for instance, the project relied on the Forest & Forest Ecosystem Condition Survey (an NFI type assessment) for data on trees in forest areas, and carried out a specific assessment exclusively focusing on non-forest land.

This assessment began with the identification of all the land-cover classes with trees (10 classes in this case). A systematic sampling of the country's non-forest area was then used for mapping and measuring the area of each class, based on the analysis of high-resolution remote-sensing data sets. Each class was then assessed for its wood potential through measurements in a random sample of field plots.

The Land Degradation Assessment in Drylands (LADA) is another international supporting programme. It involves the United Nations Environment Program (UNEP) and FAO, and it aims at assessing the causes and impacts of land degradation at global, national and local scales (see Part 2b: LADA TOF profile). At national scale, LADA works with a panel of national partners and, after having mapped areas identified as hotspots of land degradation, the project carries out detailed local assessments in a few study sites located in these areas. The areas selected for local assessments may not be representative of the national distribution of TOF subsets and the small number of study sites in each selected area is not sufficient for ensuring statistical reliability and accuracy. However, each LADA local assessment provides locally detailed data on TOF. When combined with the other LADA local assessments, they may represent a complementary source of information on various TOF subsets, especially with regards to TOF management (see Part 2a: Senegal TOF profile).

3.3.b. Land-cover and land-use assessments

The need for spatial information about a country's key geographical features is at the root of the development of geography in general. Mapping is a specific field of geography which long focused on the spatial representation of topography and political boundaries, often including information on the main local uses and production of the land. Along with the technological advances of the 20th century such as high-resolution remote-sensing data and data analysis, capacity for detailed mapping of any geographical feature has become a reality. Many countries have thus developed detailed assessments of their land-use and land-cover, either independently or through collaboration with international programs.

Modern land-use and/or land cover assessments such as the eight assessments belonging to this group in this review (see Table 4) use remote-sensing datasets to produce spatial information with a level of detail that primarily depends on the resolution of the available datasets. This spatial information is translated into maps at various scales from which areas of each considered feature can be estimated. Although these assessments always involve a ground-checking phase, they are usually not associated to field measurements (but there are exceptions such as the National Inventory of Landscapes in Sweden, see Part 2a: Sweden TOF profile) and they thus only inform on the location and area of the land-use/land-cover classes. For TOF, this kind of assessment is extremely useful, both as a direct source of information on the location and area of land-use/land-cover classes with TOF, and as a basis for the identification of areas of interest for conducting detailed TOF assessments. There is however a pre-condition: that land-use/land-cover classes include classes corresponding to the main TOF categories.

All these assessments begin with the identification of all the land-use and/or land-cover classes relevant to the country, usually involving a hierarchy of levels. For instance the first level in the Natural Resources Inventory carried out in the USA (see Part 2a: USA TOF profile) involves two large classes ("developed land" and "rural land"), which are further subdivided up to the last level in ever more specific classes: as an example, "horticultural cropland" is a last-level class which is included into the "Non-cultivated cropland", which itself is part of the "cropland" class, one of the second level classes included in the "Rural land" first level. With regard to the use of the above assessment for getting information on TOF, the situation is quite mixed: some classes contain no TOF at all, some are exclusively composed of TOF, and the others are only partly composed of TOF. In the example above, the "hayland" class, a subclass of "cropland" dedicated to the production of forage crops that are machine harvested, contains no TOF at all. By contrast, the "horticultural cropland" class, also a subclass of "cropland" but dedicated to tree crops, is exclusively composed of TOF. In many cases however, only part of the last-level class includes TOF such as the "rural transportation land" class, a subclass of "developed land" covering transportation corridors in rural areas, which is sometimes associated with narrow lines of trees, which are TOF.

The fact that some land-cover/land-use classes are completely devoid of TOF, while other classes are exclusively composed of TOF and still others partly composed of TOF is typical of the classificatory frameworks used in land-cover/land-use assessments. These assessments are undoubtedly useful as they provide spatial information on classes that are exclusively composed of TOF, therefore allowing the production of some estimates of TOF at country level. However, the fact that some classes only partly contain TOF is problematic, as there is no means to know which parts of such classes contain TOF and which parts do not. Even quite sophisticated assessments such as Corine Land Cover developed at the european scale, and assessments that use the Land Cover Classification System (LCCS, Gregorio & Jansen 2000) developed by FAO and UNEP (see Part 2b: Land Cover Classification System TOF profile) have classes that only partly contain TOF, such as the "Fruit trees and berry plantations" in Corine Land Cover, which could be considered a TOF category except that it includes "permanent florist plantations of roses"; or the "Small Tree Plantation" class in the Land Cover mapping - LCCS project implemented in Senegal, which gathers all forest tree plantations with less than 2 ha in area ("Other Land *with TOF*" for those plantations between 0.05 and 0.5 ha, "Forest" for plantations between 0.5 and 2 ha). In the same Senegal Land Cover Mapping project (see Part 2a: Senegal TOF profile), among the 55 land-cover classes represented in the country, 8 classes could be identified as containing TOF in all the areas they cover (2 classes related to tree-crops, 3 classes related to rain-fed herbaceous crops with a layer of sparse trees, 1 class related to natural herbaceous vegetation with sparse trees and shrubs, 1 class related to urban areas and 1 class related to rural settlements), but 13 classes were identified as containing TOF in parts of the area they cover: 12 classes are subclasses of "Terrestrial Natural Vegetation" and 1 is a subclass of "Aquatic Natural Vegetation", and for these 13 classes, this is either the area of the unit (more or less than 0.5 ha) or the tree cover in the unit (more or less than 5 percent) that determines whether the area does or does not contain TOF.

The Land Cover Classification System, despite the constraints exemplified in the Senegal example above, warrants a special mention here for four reasons:

- ✓ It has been developed through a large range of international collaborative activities by a very diverse panel of national and international experts;
- ✓ After testing in various countries, it has been implemented in a number of countries and it is now used by an increasing number of national, regional and international programs;
- ✓ The land-cover classification approach adopted by LCCS, combining a set of universally applicable levels and 8 optional sets of classifiers, allows levels of detail that are adapted to any country;
- ✓ And the system may be improved in its usefulness for TOF assessments through the adoption of judiciously selected TOF-related classifiers.

3.3.c. National Forest Inventories

Although they usually focus on forests, National Forest Inventories (NFI) or their equivalent may almost always be a source of information on TOF, as shown by the 14 assessments belonging to this group in this review (see Table 4). They often include some TOF categories; they always focus on biophysical information related to trees and their environment; and they sometimes also include socio-economic data.

NFIs sometimes assess TOF that are located in forest areas

The three examples below highlight the fact that national definitions of forest may be different from the FAO definition (Lund, 2002). That suggests that some TOF subsets may be included in NFI assessments and therefore extractable from NFI data.

In Slovenia, national law defines forest as "forest tree stands > 0.25 ha and riverside forest corridors and windbreaks > 0.25 ha, if their widths are at least one tree-height". Small woodlands between 0.25 ha and 0.5 ha were thus considered as forest in the Slovenia "Forest & Forest Ecosystem Condition Survey" (FECS), an NFI equivalent. It was carried out in 2007 at country scale and covered only the country forests (see Part 2a: Slovenia TOF profile). For FAO, since these small woodlands are less than 0.5 ha in area, they are not considered as Forest and the trees are considered as TOF.

In the USA (see Part 2a: USA TOF profile), the Forest Inventory and Analysis program carries out periodic assessments on "accessible forest land," defined among other points as an area that is occupied by trees with at least 10 percent canopy cover, and that meets minimum area (0.4 ha) and width (36.6 m) requirements. These criteria allow (i) small woods between 0.4 and 0.5 ha, and (ii) linear tree formations

with a width between 20 and 36.6 m, to be included in these accessible forest lands. For FAO, they are TOF and make up part of the TOF subset N1 and of the TOF subset N2, respectively (see Chapter 2).

In India, TOF are assessed through two specific assessments (the "TOF Urban" inventory and the "TOF Rural" inventory: see II.1.2. and II.1.3. above). Another national assessment, the "Forest Inventory", should also be taken into account for a more complete assessment of TOF (see Part 2a: India TOF profile). The Forest Inventory is a periodic assessment that focuses on forest land. However forest land is not always well demarcated in the field, so that an estimated 10 percent of the area assessed is located on non forest land. It is therefore no surprise that the Indian Forest Inventory includes categories that qualify as TOF, such as "Agricultural Tree Land", "Trees in Line", "Agricultural Lands with Trees in Surround", and "Non Forestry Plantations".

NFIs often encompass non-forest land

Some countries conduct their NFI through a systematic sampling grid that encompasses both forest land and non-forest land, with field and/or remote-sensing sampling in the two components. This means that they collect information on TOF in both their forest land (because of differences between national definitions and FAO definitions) and in their non-forest land, albeit usually with different sampling intensities and sampling protocols.

The National Forest Inventories conducted in Canada (see Part 2a: Canada TOF profile) and in countries that have implemented the National Forest Monitoring and Assessment methodology developed by FAO (NFMA) are good examples of assessments that cover both forest land and non-forest land through different sampling schemes.

The Canada National Forest Inventory is based on a sampling grid that covers the whole country regardless of land cover. Remote sensing sampling plots are assessed whether they are forested or not, but field measurements are carried out only in forested plots.

Countries that used the methodology developed by the National Forest Monitoring and Assessment programme represent other national examples of assessments based on a systematic grid covering the whole country regardless of land use. Here, field sampling and measurements protocols differ depending on whether the sampling unit is located on forest or not (see Part 2b: NFMA TOF profile). Among countries that have implemented NFMA assessments to date, only Cameroon and Guatemala have subdivided their land territory, in 2 and 3 regions respectively that differ in terms of their forest cover. In these cases, forest-dominated regions have twice the sampling intensity of non-forest dominated regions. However as a rule, the measurements protocols in NFMA type assessments are different for forest and non-forest Land-Use/Cover Sections (LUCS), with fewer trees measured on non-forest LUCS because the minimum DBH for tree measurement is higher than on forest LUCS (see Part 2a: Bangladesh TOF profile; Nicaragua TOF profile; Philippines TOF profile; Zambia TOF profile). The originality of the NFMA approach, compared to other NFIs and their equivalent, is that TOF are taken into account right at the onset of the assessment through the constitution of a multi-sector coordination panel, through the multidisciplinary nature of the field teams, and through the inclusion of classes containing TOF in the Land-Use/Cover Classes identification process. This effort allows the mapping and measurement of the sections covered by these classes in field samples, completed by interviews with locals that inform on various management,

production and socio-economic issues. NFMA assessments have thus the potential to produce various spatial, biophysical and socio-economic estimates relative to TOF, however with the same constraint as other NFIs: they do not directly provide spatial information on the location of the various TOF classes (although they are often associated with a land-cover assessment that may fill this role). And although they are statistically reliable, they have a relatively low accuracy for TOF due to the low number of field samples including TOF and the high heterogeneity of TOF systems.

The National Forest Inventories in China (see Part 2a: China TOF profile), Norway (see Part 2a: Norway TOF profile) and Sweden (see Part 2a: Sweden TOF profile) represent rare examples of assessments that cover both forest land and non-forest land by using the same sampling scheme for both land-uses. The three countries use quite different methodologies, specific to each country, but they implement the same sampling and measurements schemes regardless of the land-use category, be it forest or not.

NFIs: provider of information on TOF, but also of tools and methods for large-area TOF assessments

Among the data recorded in all NFIs, species identification and dendrometric measures have a special place. Their analysis is of prime importance for assessing the current state of the tree resource in general, for both forest and for trees outside forests. Trees in and outside forests indeed share a number of features, as regards the goods and services they provide. Trees in forests usually produce timber, but in some areas, trees outside forests are a major source of timber, at least for local users (Pandey 2008, Bertomeu 2008). Forests also produce non-timber forest products (NTFPs) but in many cases, they are also collected from trees outside forests that are very often cultivated (Ruiz-Perez et al 2004). Usually the land use of origin of NTFPs is difficult to trace, so that it is often impossible at national scale to know the proportion of a given NTFP coming from forest or from TOF. Trees in and outside forests also provide the same range of environmental services, albeit with varying degrees according to the organisation and composition of the trees.
As shown above and in the country TOF profiles, most NFIs already provide some information on TOF, but considering the functional commonalities between trees in and outside forests, the main utility of NFIs for TOF assessment in large areas may well be as a source of ideas for tools and methods that could be adapted.

3.3.d. Cross-analysis

This section reviews the main characteristics of TOF-related assessments and identifies the major commonalities and differences among the various assessment types (cf Table 5).

Objective(s) of the assessment

Objectives of the assessments always involve a better understanding and knowledge of the targeted resources with the aim of improving planning and resource management. The assessment's land-use coverage clearly depends on the targeted resources: land-use/land-cover (LU/LC) type assessments include all land uses; national forest inventories include forest only or all land uses; and TOF-specific assessments include one, two, or three TOF sets. For a TOF set, inclusion in an assessment does not mean that the TOF set is explicitly taken into account. For instance, many LU/LC assessments do recognize and explicitly take into account tree-crop monoculture plantations, but place pastures with isolated trees into a broader "pasture" category.

Institutions involved and coordinating institution of the assessment

The coordinating institution may belong to the forestry, agriculture, environment or academic sectors. The assessment sometimes involves institutions in other sectors. With the exception –in our sample- of the Sweden NFI (which is coordinated and implemented by an academic institution), national forest inventories are always coordinated by a forestry agency. Other sectors are generally not involved in the implementation of NFIs except when their objectives extend beyond the forest resource and thus include the tree resources outside forests. Most land-use/land-cover assessments are coordinated and implemented by institutions in the environmental sector.

Some LU/LC assessments involve institutions in other sectors during implementation. TOF-specific assessments are generally coordinated by the institution in charge of the targeted TOF set(s): agriculture for the tree-crops census or surveys, forestry for linear tree formations and for small woods, and municipalities for urban tree surveys. However, there are many exceptions. For instance, urban forestry assessments may be coordinated by a forestry agency (India, Slovenia, USA), by a higher education agency (Sweden) or by an inter-sectoral agency (UK).

Table 5: Main characteristics of the assessments analyzed in the review

Assessment	Assessment Type	Institution in charge (a)	Multi sector	Objectives (b)	Scale (c) / land area (x 1000 ha)	Targeted Land-uses (d)	Forest definitions (e)
Europe - CORINE LAND COVER	LULC	E	N	I	R (Europe)	I	NotFRA
India FC/TC Assessment	LULC	F	N	F	N / 297 319	I	NotFRA
Morocco Globcover LC 2008	LULC	I	N	I	N / 44 630	I	NotFRA
New Zealand LCDB2	LULC	E	N	I	N / 26 771	I	NotFRA
New Zealand LUCAS	LULC	E	Y	I	N / 26 771	I	NotFRA
Senegal Land-Cover mapping	LULC	E/I	Y	I	N / 19 253	I	NotFRA
US NRI	LULC	A/E	N	I	N / 916 193	I	NotFRA
Sweden NILS	LULC	E	Y	I	N / 41 033	I	FRA
Morocco NFI	NFI	F	N	F	N / 71 255	F	NotFRA
Uruguay NFI	NFI	F	N	F	N / 17 502	F	NotFRA
Slovenia FFECS	NFI	F	N	F	N / 2 014	F	NotFRA
US FIA	NFI	F	N	F	N / 916 193	F	NotFRA
China NFI	NFI	F	N	F	N / 942 530	I	NotFRA
Norway NFI	NFI	F	N	F	N / 30 427	I	NotFRA
Senegal - PROGEDE	NFI	F	Y	F	N / 19 253	I	NotFRA
Bangladesh NFTA	NFI	F	Y	F/I	N / 13 017	I	FRA
Canada NFI	NFI	F	N	F/I	N / 909 351	I	FRA
Zambia ILUA	NFI	F	Y	I	N / 74 339	I	FRA
Cameroon NFRA	NFI	F	Y	I	N / 47 271	I	FRA
Nicaragua NFI	NFI	F	Y	I	N / 12 140	I	FRA
Philippines NFTRA	NFI	F	Y	I	N / 29 817	I	FRA
Sweden NFI	NFI	H	N	F	N / 41 033	I	FRA
Global - Trees on Farm	TOF specific	H	N	A	G	A	n.a.
Morocco Citrus Census	TOF specific	A	N	A	N / 71 255	A	NotFRA
New Zealand APS	TOF specific	I (A/F)	Y	A	sN / 26 771	A (partly)	NotFRA
UK - Fruit and Orchard Survey	TOF specific	A	N	A	sN / 16 459	A (partly)	NotFRA
Uruguay GCA	TOF specific	A	N	A	N / 17 502	A	NotFRA
US Great Plain States - Non Forest	TOF specific	F	Y	A/U	sN / 79 628	A/U	NotFRA
India TOF inventory	TOF specific	F	N	A/U	N / 297 319	A/U/L	NotFRA
Slovenia - WISDOM	TOF specific	F	N	A/U	N / 2 014	All except F	NotFRA
UK - Small Woods	TOF specific	F	Y	F/A	sN / 22 894	F/A/L	NotFRA
UK - Countryside Survey	TOF specific	E/H	Y	F/A/L	N / 24 250	F/A/L	NotFRA
France - Linear formations	TOF specific	F	N	L	N / 55 010	L	FRA
Italy - Hedgerows / small woods	TOF specific	F	N	L	N / 29 411	L	FRA
UK - Trees in Towns II	TOF specific	I	Y	U	sN / 13 028	U	NotFRA
Canada - Toronto UTCA	TOF specific	U	Y	U	sN / 66	U	NotFRA
US - Urban Forestry	TOF specific	F	Y	U	N / 916 193	U	NotFRA
Sweden - Urban Forestry	TOF specific	H	N	U	N / 41 033	U (partly)	FRA

Legend:

The symbol (a) refers to the sector of the institution in charge: F - forestry, A - agriculture, U - urban, E - Environment, H - Higher Education, I - integrated or multisector.

The symbol (b) refers to the main target of the assessment: F - forest resources, A - tree resource in agricultural land, U - tree resource in urban land,L - tree resource in linear formations, I - tree resource in general

The symbol (c) refers to whether the assessment covers the globe (G), a region (R), a whole country (national: N) or a large fraction of the country (sub-national: SN)

The symbol (d) refers to the land-uses targeted by the assessment: F - forest, A - agricultural land, U - urban land, L - linear tree formations, I - all land-uses

The symbol (e) refers to whether the country uses the same definitions as FAO-FRA (FRA) or not (NotFRA) for forest and related terms

Table 5: Main characteristics of the assessments analysed in the review (continued)

Assessment	Methodology			TOF variables (h)	TOF as categories (i)	Results extractable (j)
	Survey	Remote-sensing (f)	Field sampling (TOF) (g)			
Europe - CORINE LAND COVER	N	WW	N	A/Lo	P	P (re-analysis)
India FC/TC Assessment	N	WW	N	A/Lo	P (A/U)	P (A/U)
Morocco Globcover LC 2008	N	WW	N	A/Lo	P (A)	P (A)
New Zealand LCDB2	N	WW	N	A/Lo	P	P
New Zealand LUCAS	N	WW	N	A/Lo	P	P
Senegal Land-Cover mapping	N	WW	N	A/Lo	P (All)	P
US NRI	N	S	N	A/Lo	N	P (re-analysis)
Sweden NILS	N	S	Sy	D/En/Lu/M/Sp/Tc	P	P (re-analysis)
Morocco NFI	N	S	R/Sy	D/Sp	N	P (re-analysis)
Uruguay NFI	N	WW	Sy	D/En/Lu/Sp/Tc/Ten	P (A/N1/N2)	P (re-analysis)
Slovenia FFECS	N	Y	Sy	D/En/Lu/Sp/Tc/Ten	N	N
US FIA	N	S/WW	R/Sy	D/En/Lu/Sp/Tc/Ten	N	P (re-analysis)
China NFI	N	S	Sy	D/En/Lu/Sp/Tc/Ten	P	P (re-analysis)
Norway NFI	N	N	Sy	D/En/Lu/Sp/Tc/Ten	N	P (re-analysis)
Senegal - PROGEDE	N	S/WW	O	D/Lu/Sp	N	P (re-analysis)
Bangladesh NFTA	Y	WW	Sy	All (- A/Lo)	P (A/U)	P (A/U)
Canada NFI	N	S	N	A	P (A/U)	P (A/U)
Zambia ILUA	Y	WW	Sy	All	P (A/U/L)	P (A/U/L)
Cameroon NFRA	Y	N	Sy	All (- A/Lo)	P (A/U)	P (A/U)
Nicaragua NFI	Y	N	Sy	All (- A/Lo)	P (A)	P (A/N3/N4)
Philippines NFTRA	Y	N	Sy	All (- A/Lo)	P (A)	P (A)
Sweden NFI	N	N	Sy	D/En/Lu/Sp/Tc/Ten	Y	P (re-analysis)
Global - Trees on Farm	N	WW	N	A/Lo/Lu/Tc	Y	Y (A)
Morocco Citrus Census	Y	WW	Sy	A/Lo/Ec/Lu/M/Ten	Y	Y (A)
New Zealand APS	Y	N	N	A/Lo/Ec/Lu/M/Ten	Y	Y (A)
UK - Fruit and Orchard Survey	Y	N	N	A/Lo/Ec/Lu/M/Ten	Y	Y (A)
Uruguay GCA	Y	N	N	A/Lo/Ec/Lu/M/Ten	Y	Y (A)
US Great Plain States	N	WW	R/Sy	D/En/Lu/Sp/Tc	Y	Y (A/U)
India TOF inventory	N	S	Sy/St	D/Lu/Sp/Tc/Ten	Y	Y (A/U)
Slovenia - WISDOM	N	S	Sy	D/Lu/Sp/Tc	Y	Y (A/U)
UK - Small Woods	N	S	Sy	D/En/Lu/Sp/Tc/Ten	Y	P (re-analysis)
UK - Countryside Survey	N	WW	Sy	All (- Ec/TP/TP)	Y	P (re-analysis)
France - Linear formations	N	S	Sy/St	D/En/Lu/Sp/Tc/Ten	Y	Y (N2)
Italy - Hedgerows / small woods	N	S	Sy/ST/R	D/En/Lu/M/Sp/Tc/Ten (l)	Y	Y (N1/N2)
UK - Trees in Towns II	Y	S	R	A/Lo/D/Ec/Lu/M/Tc/Ten	Y	Y (U)
Canada - Toronto UTCA	N	WW	Sy	D/Lu/Sp/Tc/Ten	Y	Y (U)
US - Urban Forestry	N	S/WW	N	A/Lo/Lu/Tc	Y	Y (U)
Sweden - Urban Forestry	Y	N	N	Lu/M/Tc	Y	Y (U)

Legend

The symbol (f) refers to whether the assessment includes the analysis of Remote Sensing images: N - no, S - on a sample of locations, WW - wall to wall mapping (on the whole area covered by the assessment)

The symbol (g) refers to whether the assessment includes a Field sampling phase: N - no, R - random sampling, Sy - systematic sampling, St - stratification per TOF categories, O - other type of sampling

The symbol (h) refers to TOF variables measured or assessed: A - area, D - dendrometrics, Ec - economics, En - environment, Lo - Location, Lu - land-use, M - management, Sp - species composition, TC - tree cover, Ten - Tenure, TP - tree products, TU - tree uses

The symbol (i) refers to whether TOF are Y - fully taken in account, N - not taken in account, or P - partly taken in account, in categories of the assessment,

The symbol (j) refers to whether TOF results are Y - extractable for all TOF subsets concerned by the assessment, N - not extractable for any of the TOF subsets, P - partly extractable, only for some of the subsets concerned by the assessment, or P (data re-analysis) - partly extractable through a re-analysis of the raw data.

Methods used for the assessment,

As expected, the assessments reviewed use remote-sensing analysis usually combined with mapping, field inventories and/or survey questionnaires. The analysis confirms that the three main methods complement each other, with each main method being associated with a different set of variables.

Remote-sensing analysis

All land-use / land-cover assessments use remote-sensing analysis. When the production of LU/LC maps is not among the assessment's expected results, the main objective is the production of statistically valid data at national scale, as in the Sweden NILS and the US NRI. In those cases, the assessment is based on analysis of a set of high-resolution images that are uniformly sampled from a grid covering the entire targeted area. When the assessment results in LU/LC maps, such as in the other LU/LC assessments, the analysis of images covering the entire targeted area ("wall to wall") is necessary. Due to the cost in terms of images and analysis, low-resolution images are used for this wall-to-wall mapping, generally in combination with a sample set of high-resolution images used for reference data creation. Most national forest inventories use existing LU/LC assessments as secondary data, often to check for the presence of forest in samples targeted for field measurements. But some NFIs include an LU/LC assessment in their activities and use remote-sensing analysis, either with wall-to-wall images or with uniformly spaced sample images on a grid. Most TOF-specific assessments include a remote-sensing analysis phase, either with wall-to wall images when maps are to be produced, and/or with uniformly spaced sample images.

The variables related to TOF that are assessed through wall-to-wall remote-sensing are the location and the area of the LU/LC units. The tree cover in each unit may also be assessed, as exemplified at global scale by the "Trees on Farm" assessment. Remote-sensing image samples can be used to estimate at country scale the area and the tree cover of various LU/LC classes and subclasses. Other biophysical variables related to trees in or outside forests, such as biomass and carbon stocks, have been estimated from remote-sensing images, but mainly in relatively homogeneous areas and/or small areas. New remote-sensing methodologies based on Light Detection And Ranging (LiDAR) technology could be of particular importance to TOF assessment. LiDAR technology has numerous applications especially in forestry due to its capability to measure tree heights and in some cases biomass (REF). Remote-sensing is a very active field of research and progress will most likely allow estimation of more variables than area and tree-cover on a routine basis in the near future.

Field inventories

Although all the land-use/land-cover assessments include a ground-checking phase, none of the reviewed assessments includes real field inventories, except the Sweden NILS, which combines analysis of uniformly spaced, high-resolution images with field inventories in the areas covered by these images. By contrast, all the national forest inventories are based on important field inventory campaigns, which in the large majority of cases involve uniformly spaced field samples (systematic sampling), sometimes associated with a certain level of randomization. The situation is more varied in TOF specific assessments. No field inventory is included in agricultural censuses or surveys focusing on tree crops. Field inventories are not included in some urban tree assessments, but they are in others where the location of field samples is chosen through random sampling (UK Trees

in Town) or through systematic sampling combined with a degree of stratification (India TOF-urban) or not (Canada-Toronto UTCA). In assessments focusing on TOF groups other than the previous ones, such as narrow linear tree formations, small woods and rural TOF, field inventory is always a major component. Location of field samples is always based on a systematic sampling scheme, which sometimes includes some level of stratification and/or randomization.

The variables associated to TOF that are assessed through field inventories are biophysical variables. The list can be extended almost ad infinitum, but the minimal set consists of the identification of tree species, dendrometric variables such as tree diameter (DBH), tree height, tree cover, environment variables, such as soil characterization, slope, herbaceous components, etc. These variables are used to characterize the structure and composition of the tree component in the field sample. They are further used to derive estimates at national (or other level) level of the tree density, basal area, wood volume, biomass, carbon stocks, etc. The minimum set of variables usually also includes information on land use and land tenure.

Survey questionnaires

Survey questionnaires are not included in any of the land-use/land cover assessments, nor are they included in the national forest inventories, except in NFIs that used the NFMA approach. Survey questionnaires have only been used in TOF-specific assessments that focus on tree- crops, where they make up the main tool for collecting data, and for some urban tree assessments.

The variables related to TOF usually captured through survey questionnaires are socio-economic, production and management variables. The list of such variables usually include basic socio-economic information on the owner or manager of the plot used for sampling, the identification of the various products associated to each tree species, the yield for each product, the quantity of product sold, the sale price, and the management practices (planting, cutting, pruning, etc.) associated with each tree species and the plot.

Identification of categories with TOF in the assessment

Land-use/land-cover assessments generally include LU/LC classes that contain no TOF at all, classes that contain TOF in all the area they cover, and classes that contain TOF only in parts of the area they cover, as exemplified above in the case of the Senegal land-cover mapping (see Chapter 3, 3.3.b). In Senegal for instance, the minimum area and tree cover thresholds are different from those used by the FAO-FRA; that explains the existence of undetermined classes for TOF (classes that may or may not contain TOF depending on the location). In other cases, the class definition does not include the presence (or absence) of trees in its criteria. For instance the class "pasture" often does not differentiate pastures with trees from pastures without trees. National forest inventories often do not include explicit TOF categories but some NFIs do. One example is the Sweden NFI, which developed a very detailed classification; another is the Canada NFI, which uses the FAO-FRA "Other Land with Tree Cover" class; finally there are all the countries that have implemented the NFMA approach and that have explicitly categorized agricultural TOF, sometimes also urban TOF, and but more rarely small woods and/or narrow linear formations. Quite logically, all TOF specific assessments include explicit TOF categories, although none of the reviewed assessments includes all the categories.

TOF sets covered by the assessment

There is an obvious relation between the targeted land-uses of an assessment and the TOF sets that are included into the coverage of this assessment. Land-use/land-cover assessments target all land-uses and very logically include all TOF sets in their coverage. National forest inventories often also target all land-uses which entails that all TOF sets are covered, but a few NFIs more exclusively target forest, which restricts the number of TOF sets that may be found in the assessment coverage with TOF-URB being always excluded. TOF specific assessments very logically show a very close relation between the targeted land-uses and the TOF sets and subsets that are included in the coverage of the assessment. Except for this latest category – TOF specific assessments – it is important to note that the data produced on a given TOF set depend not only from the coverage of the assessment, but also from its objectives and its capacity to distinguish explicitly between the various TOF sets. For a given TOF set to be included in the coverage of an assessment is no guaranty that the assessment produces relevant information on this TOF set. For instance, almost no data can be found on small woods in LU/LC assessments and NFI assessments –because small woods are… too small!-, although this is a TOF subset (N1 in table 5) that is included into the coverage of all the LU/LC assessments and of almost all the NFI assessments.

Main kind of results regarding TOF at the scale of the assessment

The kind of results regarding TOF highly depends on the type of assessment, and within each type, on the targeted land-uses and the combination of methods used. Land-use/land-cover assessments that include mapping, as well as national forest inventories that include a LU/LC phase, provide results on the locations with TOF at least for the TOF categories that have been explicitly defined. All LU/LC and NFI assessments estimate the extent of each explicitly defined TOF category. For mixed categories in which TOF may or not be present, data might be extractable but this would involve a re-analysis of the raw data. National forest inventories mainly provide biophysical and species composition data and information on the main land uses and land-tenure status, again for those TOF categories that have been initially explicitly identified. For these categories, in addition to the area they cover, NFIs may provide estimates at the assessment scale of variables such as the number of trees, the relative proportion of the major tree species, the total tree biomass, the total timber stock, and the total carbon stock. For mixed categories in which TOF may or not be present, the situation is the same as for spatial distribution and area: data might be extractable but this would involve a re-analysis of the raw data. NFIs that used the NFMA approach usually also provide socio-economic results of high importance for TOF issues, such as the use of TOF products and the trends in harvesting these products, or the gender balance in the harvesting and use of TOF products, etc.

TOF-specific assessments are more heterogeneous in all aspects, including the kind of results produced. The global "Tree on farm" assessment produced a number of global and regional maps, including inter alia maps of the tree cover on agricultural

land, as well as global and regional estimates of the areas of agricultural land with tree cover according to various thresholds. The national agricultural surveys produce estimates of various socio-economic and management data relative to the producers, estimates of the areas under various tree crops, and estimates of the yield and annual production of the various tree crops. But they generally do not include any dendrometric data so that other biophysical estimates – such as tree biomass and carbon stock -- cannot be provided by these surveys. The other TOF-specific assessments generally provide very detailed results regarding the TOF categories they focus on. In addition to estimates of the extent of the targeted TOF category, results generally include estimates of the same biophysical variables as for national forest inventories (tree number, biomass, carbon stock, composition, etc.), and in some urban forestry assessments, estimates of TOF products, services and management.

Three main observations here involve:

- ✓ The relationship between the kind of assessment and the kind of institution in charge;
- ✓ The relation between the kind of assessment and the sets of methods;
- ✓ The kind of results produced by each kind of assessment.

The institutions involved in the organisation and coordination of the assessments reviewed here are diverse and represent various sectors.

National TOF specific assessments have been implemented by national forest services alone in India (TOF Urban and TOF Rural), France (Linear Tree Features Inventory), and the USA (Great Plain States – Non Forest). In three other cases

(WISDOM Slovenia, the Forest on the Edge project in USA, and the Small Woodland and Tree Survey in UK), the national forest services were coordinators, but the assessment involved many partners from various sectors. In the Trees in Town project in England, the national forest service was one partner in a multi-sector collaborative assessment coordinated by the Department for Communities and Local Government. The Agriculture Production surveys are obviously part of the domain of the national agriculture services. Among the other large-scale assessments that provide information on TOF, National Forest Inventories and their equivalents obviously are the primary domain of national forest services. The "Trees on Farm" global study on agroforestry was carried out by an international research centre (ICRAF), using data produced by Land-cover/ land-use (LC/LU) assessments. LC/LU assessments themselves most often involve international partners such as the Global Land Cover Network (GLCN) and national services related to land-use planning, agriculture, forestry and environment in a multi-sector collaborative process. NFMA-

type assessments are usually coordinated by forest services but they always involve a multi-sector collaboration.

Some assessments such as the "Agriculture Production Surveys" in UK and New Zealand or the "Survey of Urban Forestry" in Sweden were exclusively carried out through survey questionnaires sent throughout the country to targeted individuals. The land-cover and land-use assessments all use remote-sensing derived datasets associated with ground-checking, and result in the stratification of a country territory in hierarchically organised land-cover/land-use classes. NFIs and their equivalent, but also the TOF focused assessments, all use a combination of remote-sensing derived datasets and field sampling inventories. They also all use a fairly complex combination of all or part of the following elements, at various stages of their sampling schemes : stratification (e.g., "accessible forest land" vs. "non-forest tree land" in the US FIA, or "block" vs. "linear" vs. "isolated" in the Indian "TOF rural" inventory), systematic grid (e.g., NFI in China, Sweden, USA, and NFMAs), and random sampling (urban blocks in the Indian "TOF urban" inventory, field sub-plots in the UK "Survey of Small Woodland and Trees").

Each kind of assessment yields certain kinds of results. Land-cover/land-use assessments are targeted towards the production of spatial results. For TOF, the usefulness of such assessments is directly related to the identification of unequivocal TOF categories that cover the whole TOF range. The reliability and accuracy of results on TOF classes, as for any LC/LU class then mainly depends on the quality and resolution of the remote-sensing data used. Data are generally presented as maps, and allow the production of estimates of the area covered by each LU/LC class. The usefulness of such data for more detailed TOF assessments is obvious: all patches of each TOF class may be located, allowing the development of adapted sampling strategies that take into account the heterogeneity of each class as well as their geographical distribution and their total area. National Forest Inventories and their equivalents, including NFMA type inventories, in forest land and when the area of isolated stands is recorded, may provide data contributing to an estimation of both the area and the tree attributes of small woodlands less than 0.5 ha in area; in non-forest land, when land use is recorded, they may provide estimates of the area and tree attributes of both trees in an agricultural context and trees in an urban context. Agricultural production surveys provide data that contribute to estimation of the area and attributes of trees in an agricultural context.

TOF-focused assessments provide various kinds of data depending on the objectives set for them. To give one example in an urban context, the Forest on the Edge project in the USA provides data at national scale on the areas of urban land with trees, as well as on the tree density and the tree cover in these areas. The Trees in Town inventory in the UK and the TOF Urban Inventory in India provide the same kind of results, but add solid data on various biophysical, managerial and socio-economic aspects of trees in cities and towns.

3.4. Conclusions

This section highlights the main findings of this review, and examines possible reasons for the small number of large-area TOF assessments.

3.4.a. Highlighting the main results

The review of the 36 national assessments included in this report suggests that the TOF concept has not been fully integrated yet. This is clear from the following facts:

- ✓ Most non-TOF-specific assessments do not explicitly recognize the categories of TOF-covered land.
- ✓ No country has yet implemented an assessment covering all TOF sets.
- ✓ Only a very few countries have conducted assessments that deliberately targeted one or the other TOF set.

However, the review also shows that progress has been made towards the recognition of TOF as a valuable resource worthy of assessment. This is shown inter alia by the following facts:

- ✓ One global-scale TOF assessment has been realised (Trees on Farm). It concerns only TOF on agricultural land, but although its scope is limited to one TOF set, its results are extremely important, especially because they provide an order of magnitude of the global extent of this important set: approximately 10 million km² of agriculture area (or 46 percent of the total "agriculture land") have more than 10 percent tree cover. In other words these 10 million km² would have been classified as Forest if the land-use was not agriculture. Compared to the total area of Forest, estimated by the global FRA 2010 at 40 million km² (FAO 2010a), this is a very significant figure.
- ✓ One regional scale assessment has been undertaken (Europe - Corine Land Cover). Although it is a land-use/land-cover assessment that does not specifically focus on TOF, it encompasses various classes that contain TOF in their whole or in part of their area. Maps of the various countries are published where the spatial distribution of classes including TOF may be identified and their extent estimated.
- ✓ Many countries have available national assessments that provide (or may provide after some re-analysis of the data) information on TOF sets and subsets. It is possible for such countries to build on these assessments and develop complementary assessments that would fill the gap of information and help these countries get a more complete and accurate picture of their TOF resource. In particular, land-cover/land-use assessments constitute a perfect starting point for complementary TOF assessments based on field inventories, providing the land-cover classes have been judiciously defined so that they unequivocally cover all TOF categories.
- ✓ Countries that have implemented the NFMA approach have successfully integrated TOF and TOF issues into their national forest inventories. These countries are among the few that may provide convincing estimates of the various variables related to TOF resources.

✓ Some countries like Sweden have implemented assessments of their tree and forest resource that are so detailed that these assessments may be used for providing estimates of the main biophysical variables relative to TOF, while a few countries such as India and the UK have undertaken a set of specific TOF assessments with a focus on one TOF set or another. These TOF-specific assessments can be combined and complemented if necessary with other assessments to create a quite complete, reliable and accurate picture of their national TOF situation. These countries show that assessing all TOF at national scale is possible. There are no insurmountable technical or methodological obstacles for doing so, as long as the TOF categories are consistent across the assessments and the assessments organized in a complementary way.

Progress has been made since the previous FAO report on TOF published in 2002. So the time may be ripe for large-area assessments that fully integrate the TOF concept. However the fact that only a very small number of countries have conducted assessments that deliberately target TOF is worth investigating. The first reason is that, despite international and national efforts to focus the attention of policy- and decision-makers on their environmental and socio-economic importance, TOF and TOF assessments have been a low priority for national policy makers, except in a very small number of countries. Other reasons, linked to TOF specificities, are examined in the next section.

3.4.b. TOF specificities and TOF assessments

Chapter 2 underlined the heterogeneity and dispersion of the TOF realm and more precisely of its land-based equivalent -Other Land *with TOF*. This heterogeneity and dispersion needs to be taken into account in any TOF assessment, especially as regards the categorization of Other Land *with TOF*, the methodological and technical aspects, and the institutional framework.

The need for an explicit categorization of land with TOF

The above review shows that many land-use/land-cover and national forest inventory assessments include the whole range or a major part of the TOF sets in their coverage. However, these TOF sets are not explicitly recognized as categories in most of these assessments. The result is that information on TOF is generally not provided by these assessments although some could be extracted, provided data are re-analysed with TOF sets being explicitly taken into account as land categories. The only assessments that provide directly usable information and data on TOF are those that take TOF sets or subsets explicitly into account: TOF specific assessments, some land-use-land-cover assessments and the NFMA type assessments.

Any assessment that includes in its objectives the provision of data on trees outside forests should take into account the heterogeneity of the TOF realm in its planning phase, so that the land-use/land-cover classes defined for the assessment explicitly integrate the variety of TOF covered lands as categories.

The need for a clear and operational land classification including TOF

Any large area forest assessment may in theory have a "trees outside forests" category that encompasses all trees that have not been classified under the Forest category, this being true whatever the definition of Forest that is used. At global scale, the TOF concept, which has mostly been popularized by FAO in the framework of the global Forest Resource Assessment, evolved in response to the growing recognition that a significant part of the tree resource was "outside" the wooded land classes (Forest and Other Wooded Land). But the TOF concept could not be translated into operational terms yet, so that FAO member countries could not refer to any internationally accepted clear and operational definition of the land to be taken into account for the assessment and the reporting of TOF. It is important to note that the FAO-FRA process in general, and in particular its success in the adoption of a consensual standardized classificatory framework, had and still have a stimulating role on the development of national forest assessments in terms of both quantity and quality. A similar stimulating role could be played by FAO-FRA through the integration of TOF into its already existing classificatory framework, as proposed by the present report.

The present report proposes not only a clear definition of what TOF are, but also a clear and operational definition of "Other Land *with TOF*", and of its alter-ego "Other land *with no TOF*", two new sub-categories that complete and complement the FAO-FRA classificatory framework in its endeavour to take into account as much of the tree resource at national and international scales.

Methodological and technical aspects

One of the major conclusions of this review is that countries in various geographical, ecological, and political settings have been able to develop sound TOF assessments based on the judicious use of modern technologies and time-tested field inventory and survey questionnaire methods.

Assessing TOF does not impose radically different methods than assessing forests: low- and high-resolution images are used to identify land with TOF in the same way that pieces of forest are identified. Sampling for field inventory can proceed the same way as for forests. Field inventory protocols and survey questionnaires may be the same as for forest. Sampling, field inventory protocols and survey questionnaires could require an adaptation to the specificities of the targeted TOF sets and subsets, just as these methods would need to be adapted to various kinds of forest targeted in a forest assessment (e.g. savannah woodland, Acacia plantations).

One point may render TOF assessments more complicated than forest assessments: authorization of access to the sampling location could take much longer to obtain for TOF than for forest due to the higher number of stakeholders and the necessity to explain the assessment's objectives. But otherwise, assessing TOF is not more difficult than assessing forests once the TOF classes and sub-classes have been identified. TOF sets are diverse: so are natural and planted forests. Some TOF subsets have low accessibility: so are most natural forests. In fact, two major TOF sets (trees on land predominantly used for agriculture and trees in an urban environment) are much more easily accessible than most natural forests.

There is currently no major technological or methodological obstacle that would prevent or hinder the conception and implementation of large area TOF assessments.

Institutional aspects: Which role for whom?

The heterogeneity of the TOF category has important institutional consequences, as underscored in chapters 1 and 2. TOF realm is under the mandates of various sectors, depending on the TOF sets considered and associated land uses. TOF-AGRI is associated with agricultural land uses and comes under the agricultural and rural development sectors; TOF-URB is associated with settlements and comes under village and city administrations. The other TOF set, on land that is not predominantly under agricultural or urban use, shows a higher heterogeneity in terms of institutional responsibility: small woods (less than 0.5 ha) may come under the forestry, the rural development or the environment and natural resource sectors; narrow linear formations may reside in the same sectors but also in the sector that handles transportation infrastructure when associated with waterways, railways and roads; lands with a low tree or/and shrub cover may fall under the forestry or the environment and natural resource sectors.

This institutional fragmentation of the TOF realm is important for TOF assessments as it represents a difficulty not encountered in forest assessments. It means first, that the sectors above have each legitimacy in undertaking an assessment focused on the TOF set(s) and subset(s) under their mandate. It also means that a holistic TOF assessment, which would target all the TOF sets and subsets, cannot in most cases be undertaken without involving these legitimate sectors. The NFMA-type assessments show this is possible, but considering the difficulties often observed in inter-sector communications, this may partly explain the still low number of TOF assessments.

Another related problem is the unbalanced distribution of know-how relative to assessment of the tree resource. Unlike the forestry sector, other sectors generally have fewer human resources competent in tree assessment.

Indeed, because TOF are trees and shrubs, their assessment has often been viewed as being part of the forest services' domain of competence – which is correct – and also of its responsibility – which is often wrong as they have not always the legitimacy to undertake such assessments alone. In addition, especially when timber production and forest conservation are its main objectives, the forestry sector usually has only a marginal interest in assessing TOF. This is understandable when one considers each TOF set with regards to its potential interest and potential constraints for foresters and forests' services:

- ✓ Set 1, "trees on land predominantly under agricultural land use" (TOF-AGRI) is a widespread category with important functions crucial for million of farmers, functions such as soil fertility maintenance, carbon sequestration, biodiversity conservation, food and material production, feed for livestock, income generation, livelihood improvement, and contribution to national economies. The timber potential in this category may vary considerably, depending on local ecological conditions and the kind of cropping system, ranging from scattered trees in pastures to agroforests that may form vast forest-like massifs (Michon et al. 2007). Obviously anyhow, the problem of this category for foresters is not the timber potential, but the

small or nonexistent role they play in the management of trees grown in these systems: farmers are here the tree managers. The long history of confrontation between farmers and forestry officers has in many places left wounds on both sides, which explains both the reluctance of foresters to consider this category and the reluctance of farmers to see foresters in their fields.

✓ Set 2, "trees on land predominantly under urban land use" (TOF-URB), in settlements and cities, is also a widespread category with important or even crucial functions for people living in villages, cities and towns. Trees in backyards and private urban gardens are part of the private domain where foresters can hardly have any mandate. The situation is different with public parks and trees along streets, waterways and railways, but even though forest services are often involved in their management, they usually do not coordinate this management nor do they have control over the tree resource, which usually is under the control of municipalities.

✓ Set 3, "trees on land not predominantly under urban use" (TOF-NON-A/U), may be split into two groups (see section 2.2.c):

- Subsets 1 and 2, "Small isolated woods (less than 0.5 ha) and "narrow lines of trees less than 20 m width", can be encountered almost anywhere. The small individual size of these forest-like patches most often implies low timber and regeneration potential, which, associated with their often private tenure, generally makes these categories a low priority for forest services.
- Subsets 3 and 4, "land more than 0.5 ha with scattered trees less than 5 percent cover (subset 3), or land more than 0.5 ha with shrubs (height <5 m) or a mixed cover of shrubs and trees less than10 percent cover (subset 4)", are mostly restricted to difficult arid or semi-arid conditions with water resources that do not allow rapid tree growth nor more complex tree cover to develop. Trees occur at very low density and they represent extremely low timber resource potential, which makes these TOF subsets of minimal interest for forest services in terms of timber production. However, other functions may be attached to this category, such as biodiversity conservation, that could raise the interest of forest services.

The fact that forest services often have only very limited interest and institutional legitimacy in the three TOF sets that make up the TOF realm does not mean that foresters and forest services are not crucial partners for the implementation of TOF focusing assessments. Indeed they are, because they have the competencies in many aspects related to trees and time-tested methods for assessing trees. In other words, foresters and forest services must be involved in TOF-focused assessments, but they may often not be in the best position to initiate, lead and take responsibility for such assessments.

Assessments targeting the various TOF sets need an ad hoc multi-sector institutional framework that includes the forest sector for its competence and know-how in the assessment of trees, as well as all other legitimate sectors.

4. Keys for TOF assessments

Justifications (the why) and methods (the how) for doing forest assessments are now well known so that in most countries, national policy- and decision-makers have fully integrated national assessment of forest resources into their routine framework of activities. Most countries rely on specialized institutions in forestry to do fairly regular assessments and inform governments about the present and expected forest resource and its economic, social and environmental values. The same is true for agriculture.

As underscored in the introductory chapter, Trees Outside Forests clearly belongs to the non-forest side of the land-use divide, where agriculture is the dominant productive activity. Many if not most policy- and decision-makers now know about TOF resources and their importance (although they often use other names such as agroforestry, tree crops, or urban forests). Still, chapter 3 showed that, apart from a few exceptions, this knowledge has not yet been a sufficient stimulus for officials to initiate national assessments of TOF resources, much less integrate such assessments into their routine framework of activities.

There is thus an urgent need to make the methods and tools available, and to articulate the justification for and utility of national TOF assessments. This chapter presents possible constraints that impede the decision-making process leading to national TOF assessments, and details major justifications for those assessments. The last section is devoted to the methodological and technical options that countries have for the implementation of national TOF assessments once the decision is taken to assess TOF resources.

4.1. Specific constraints on TOF assessments

The analysis of the context and definitions that allow the formal definition of TOF (Chapter 2), and the review of TOF assessments pointed out the main difficulties regarding TOF assessments: namely, semantics and heterogeneity.

- ✓ "Trees outside Forests," as defined in this report, strictly refers to the FAO-FRA land classification framework. Although an unprecedented effort towards harmonization across countries has been undertaken in recent years in relation with the FAO-FRA programme (FAO 2003, 2005), many countries have their own definitions of forest for their forest assessments. This means that many countries have their own criteria regarding what they consider TOF, different from those in the FAO-FRA framework. This is not a difficulty in itself – as shown by examples such as the TOF rural and the TOF urban inventories in India, or the Survey of Small Woodlands and trees in the UK (Chapter 3)- but it is obviously a constraint to reporting harmonized data at supra-national level. This constraint can be overcome, as the success of the FRA reporting for Forest and Other Wooded Land shows, but it means that an effort has to be made for creating bridges or algorithms allowing national reporting to be translated for comparability in international reporting.

- ✓ "Trees outside Forests" in the FAO framework in fact designates "trees and shrubs" outside "Forest and Other Wooded Land". This is not a real constraint since the ambiguity in the terms is relieved through an ad hoc explanatory note.

✓ "Trees outside Forests" as a category has until this report not been translated into terms that would fit the land-use/land-cover classificatory framework for which it was carved. The sub-category "Other land with Tree Cover" (OLWTC), integrated into the FRA reporting framework in 2005, is a major attempt in this direction, as it represents an important part of the TOF resource in many countries. However, OLWTC does not take into account small tree patches (less than 0.5 ha), narrow linear formations, nor very scattered trees on large areas, three TOF-based categories that in some countries may contribute very significantly to the national TOF resource (see Box 1 - Bangladesh). To help solve this problem and translate the TOF concept into its land-based equivalent, this report proposes a subdivision of Other Land into two mutually exclusive subcategories, with the sub-category "Other Land *with TOF*" including most of the TOF resource. For this subdivision to be operational in terms of assessment, this report proposes a set of minimum thresholds, which implies that the sub-category "Other Land *with No TOF*" may include some TOF (especially very scattered trees, which in most countries represent a very minor contribution to the national tree resource).

BOX 1: TOF in Bangladesh

Source: Bangladesh National Forest and Tree Resource Assessment 2005-2007. (see Part 2)

In Bangladesh, the National Forest and Tree Resource Assessment has subdivided "cultivated land with trees" and "rural settlement with trees" into two subcategories each, depending on size: between 0.1 and 0.5 ha, and above 0.5 ha. At the country level, the total area covered by these categories is reported in the following table:

	Total area (ha)	
	0.1 to 0.5 ha	**above 0.5 ha**
Annual crops with trees	784,000	126,000
Perennial crops with trees	8,000	79,000
Rural settlement with trees	1,090,000	1,677,000
Total	**1,882,000**	**1,882,000**

The table shows that in Bangladesh, the total area of land covered with TOF on small land parcels is equal to the total area of land covered with TOF on larger parcels.
In terms of tree resource at national scale, the assessment shows that TOF are of major importance. For instance, the total aboveground wood biomass is estimated at about 846 million tons. Of this total, Forest contributes 33 percent while TOF contributes 67 percent (TOF-AGRI: 17 percent; TOF-URB: 50 percent).
Bangladesh represents a striking example in which the structure of farms and villages is such that following the area threshold used for defining the sub-category "Other Land with Tree Cover" (area ≥ 0.5 ha) would drastically reduce the estimated contribution of TOF, as it would leave a very significant part of the tree resource un-accounted.

Bangladesh is far from being devoid of trees, even in crop-fields dominated rural areas with extreme population density. Trees are planted around houses and in villages where they ensure a forest-like cover.

- ✓ "Trees Outside Forests," or more precisely "Other land *with TOF,*" is a category that presents very high heterogeneity. This heterogeneity concerns the spatial pattern of the trees, but it also concerns their functions, values, uses, as well as their dynamics and their management characteristics. "Other land *with TOF*" consists of three main sets corresponding to land uses: predominantly agricultural, predominantly urban, and predominantly non agricultural/ non urban. It thus encompasses land uses as different as coffee plantation, parking lot with shade trees in a city, or narrow linear tree formation along a water stream in an otherwise arid area. A high heterogeneity is in itself a constraint for inventories and assessments, as it entails the need for higher sampling intensity (and thus higher cost) than low heterogeneity for reaching the same precision level.

- ✓ The fact that TOF encompasses land with trees in agricultural, urban and non urban/non agricultural areas means that TOF involve a large range of stakeholders, and that the various parts of the TOF realm are each under the mandates of various institutions. This institutional dispersion may be compared to the institutional concentration that characterizes the forest sector, and is probably one of the major constraints that has prevented most countries from fully integrating TOF assessments and TOF issues into their policy framework. The situation may be relieved through the formal recognition of the different TOF sets and the subsequent recognition and integration of this institutional dispersion right at the outset.

4.2. Why do TOF assessments?

TOF assessments are needed at different levels, with purposes that are basically the same at all levels: management, monitoring and planning (see Chapter 1). At the country level, which is the main focus of this report, TOF assessments are triggered by international and national justifications that correspond to international and national stakeholders.

National policy makers and others need spatial and statistical data with guaranteed credibility on TOF that they can use for development planning and accounting of the services provided by TOF in terms of energy, food diversity and food security, among others. They use this data for identifying TOF "sectors" with high investment potential, for budgeting and allocating funds for the development of economically promising land uses with TOF, and/or land uses with TOF having a patrimonial value. Good quality data are also needed to monitor the congruency of the regulation framework, especially in terms of taxation and tenure, with the development of land-use systems with TOF in order to optimize the contribution of these systems to the national economy and to the national environment.

Farmers' national associations, city dwellers' national associations and environment national associations are other major stakeholders concerned with TOF at the national level. They need quality data on TOF for running their activities but they also can and should be partners in national TOF assessments, as assessments of TOF in agricultural and urban contexts cannot be undertaken without the active participation of farmers and city dwellers, at least when field level data are needed.

The UNFCCC, the CBD, the UNCCD, and FAO, all need much better quality data on TOF than they currently have, and this can only be done through carefully implemented national TOF assessments. This is an important justification for countries to embark on TOF assessments; this is also a major opportunity for countries, as an international emphasis on TOF will one day have to be translated by the international community, through the UN mechanisms and institutions and also through the large international development and environment NG0's, into the allocation of financial and human resources for assisting countries that need support to carry out TOF assessments.

4.3. How to do TOF assessments

TOF-focused assessments covering large areas are still few, but the examples of TOF assessment presented in Chapter 3 show that they are possible and that they do not present insurmountable methodological or technical obstacles.

The following describes the main phases composing a TOF assessment, without detailing the activities in the assessment that are not specific to TOF. It should be clear that securing sufficient funding is a sine qua non condition for implementing a tree resource assessment of any kind, and that the level of funding will condition inter alia the type of assessment to be implemented, as well as the expected type of data and precision of the estimates. It should also be stressed that a good statistical design, coupled with the rigor of subsequent statistical analysis of high-quality data, is needed to guarantee the credibility of TOF estimates. This is a critical component of any successful monitoring and assessment program (e.g. Corona et al. 2011, Fischer et al. 2012).

Preliminary phase 1: Collect and analyse existing data

A national government decision to assess TOF includes the assessment's broad objectives (for example: report to international conventions such as the UNFCCC, integrate TOF into the national accounting framework, evaluate TOF contribution to the national economy). Whatever these broad objectives, the first preliminary phase would always be collecting and analysing existing data related to TOF. It is important at this stage to collect all available assessments that potentially include information on TOF. The following questions should be answered:

- ✓ Is there a land-cover / land-use assessment that covers the whole country?

- ✓ Is there a national forest inventory or an equivalent? If yes, does this inventory cover both "forest land" and "non-forest land" or only "forest land"?
- ✓ Are there national surveys of tree crops?
- ✓ Are there assessments of particular TOF categories such as urban trees or trees on agriculture land?

Once available assessments have been collected, each assessment should be analysed and evaluated for information on TOF. If data on TOF are extractable, these should be extracted. For instance, national agricultural surveys provide data on the extent of large tree-crop areas. (Note that these data are often compiled by the FAO Statistics Division and are available online at the FAOSTAT-Agriculture website: http://www.fao.org/corp/statistics/en/.) This may be used to approximate the extent of TOF-AGRI (see Box 2: FAOSTAT-Agriculture as a source of information on TOF at national scale).

When analysing available assessments, the heterogeneity of TOF should be kept in mind so that no TOF subset is a-priori discarded. As underscored in Chapter 2, a direct consequence of TOF definition is that TOF consist of 4 major TOF sets:

- ✓ TOF-AGRI: trees in agricultural systems, such as hedges, windbreaks, orchards and non forestry tree plantations, trees in pasture, and all the various forms of agroforestry systems;
- ✓ TOF-URB: trees in a urban environment, such as trees along streets and waterways, trees in private and public gardens and parks, trees in agricultural systems located in urban and peri-urban areas;
- ✓ TOF-NON A/U 1: small isolated woods and woodlots, less than 0.5 ha in area;
- ✓ TOF-NON A/U 2 narrow lines of trees less than 20 m wide.

Trees on agricultural land

Trees in city and village

Trees in linear formation

Trees in smallwood

Box 2: FAOSTAT-Agriculture as one source of information on TOF at national scale

National agricultural surveys usually include the major non-timber tree crops. FAO regularly compiles data from these surveys and makes them available to a wide public through the FAOSTAT-Agriculture database (http://faostat.fao.org/site/339/default.aspx).

The total extent of tree crops as given by such national surveys or by FAO may be used during the preliminary phase of a national assessment to estimate the extent of the TOF-AGRI subset. The resulting figure should be considered as an estimate by default (the true extent is much larger than the estimate), because national statistics on tree crops most often do not include (1) tree species with minor economic importance, (2) small farms, (3) multispecies homegardens and agroforests, and (4) agricultural tree fences and hedges.

The two examples below (a temperate country, Spain; and a tropical country, Indonesia) were downloaded from FAOSTAT in May 2012. Data are from 2008 and they reveal a minimum TOF-AGRI extent of more than 3.5 million ha in Spain and almost 14.5 million ha in Indonesia. They show that the use of the FAOSTAT database is always feasible, although the species considered may be different.

SPAIN	
Tree crop (TOF species)	**Area (ha)**
Almonds	566 869
Apples	33 362
Apricots	18 834
Avocados	10 023
Carobs	46 404
Cherries	24 671
Chestnuts	9 800
Citrus fruit	2 242
Grapefruit	1 640
Hazelnuts	15 411
Lemons and limes	46 809
Olives	2 450 470
Oranges	153 429
Peaches and nectarines	75 425
Pears	29 216
Plums	18 695
Tangerines, Mandarines	119 875
Walnuts	7 418
TOTAL	3 630 593

INDONESIA	
Tree crop (TOF species)	**Area (ha)**
Arecanuts	125 500
Avocados	19 786
Cashew nuts, with shell	308 129
Cinnamon (canella)	81 427
Cloves	311 760
Cocoa beans	990 052
Coconuts	2 950 000
Coffee, green	977 356
Fruit, tropical	207 000
Kapok Fruit	132 646
Mangoes, mangosteens, guavas	185 196
Natural rubber	2 897 670
Nutmeg, mace and cardamoms	75 243
Oil palm fruit	5 000 000
Oranges	63 695
Tea	106 948
TOTAL	14 432 408

All documents focusing on one or the other of these categories, even if they are restricted to a limited geographical area, should also be collected. In particular, scientific publications, research reports and project reports may contain relevant information on the occurrence, local extension, etc. of some TOF systems such as treed homegardens, various agroforestry systems, or small woodlots.

Country-scale data on TOF extracted from available national assessments and more localized information on TOF found in other documents will contribute to defining the current state of knowledge related to TOF for the country.

Preliminary phase 2: Develop new data with efficient remote-sensing sampling strategies

Whatever the broad objectives defined by the government for a national TOF assessment, the second step would always consist of gathering or acquiring basic information on the spatial distribution and extent of the various sets of the Other Land *with TOF* (OL*wTOF*) category.

This phase relies on remote-sensing analysis and its associated ground checking, and can thus be fully implemented by an agency specialized in land-use/land-cover assessments. Participation by institutions representing the various sectors involved in TOF would certainly help. The precision level requested, availability of financial and human resources, and the size of the country and climatic conditions will all determine the choice of methods to be used. Technological progress in remote-sensing imagery has made it theoretically possible to identify any TOF subset, including narrow linear tree formations, small tree patches and isolated trees, on high-resolution satellite images. However, the cost of such images, and the cost for analysing all such images for large areas, is generally too high for allowing a wall to wall mapping of TOF covering a whole country. Note that opportunistic sharing and acquisition of remotely sensed data with other organizations can significantly leverage the initial high cost of high-resolution imagery, and/or significantly mitigate the processing costs of coarser, freely distributed imagery.

The recommended option is thus a three-step process beginning with the analysis of low-resolution remote-sensing data allowing a wall to wall mapping and a stratification of the landscape including strata potentially related to TOF. Note that the images needed for this step can now be acquired for free (e.g., MODIS, Landsat). The second step consists of sampling the strata of interest with high-resolution images, analysing these images, and checking the results on the ground for validating the land use (non-Forest and non-Other Wooded Land), which in many cases cannot be ascertained from remote-sensing images of any resolution. The third and final step involves the development of correlations between TOF cover estimates obtained through the analysis of high-resolution images and their equivalent obtained from analysis of low-resolution images. This final step allows the scaling-up of high-resolution data and extrapolation of these data over the entire country. Hansen et al., 2010 successfully implemented a similar approach for a global forest loss assessment.

First phase: Set up an institutional framework and define detailed operational objectives

If the aim of the TOF assessment is simply acquiring information on the spatial distribution, area, and canopy cover of the various TOF subsets, then the results obtained through the preliminary phase presented above would be enough.

But in most cases, governments will identify a much wider range of objectives, which need first to be translated into detailed operational objectives. This "translation" is the first step in the flow chart of a TOF assessment. The example of India shows that it is possible in some countries to implement detailed TOF assessments in rural and urban environments without involving other institutions outside forestry, but it is recommended that the institutions in charge of the various TOF subsets be integrated right at the outset of the assessment and that they collectively define the detailed objectives and organize the distribution of tasks and responsibilities. The examples of national forest and tree resource assessments that used the NFMA approach show that this multi-sector approach is possible and that it is also a highly efficient approach. Early involvement of institutions in various sectors may also be considered as a warranty that the detailed objectives are truly operational, through taking into account not only the financial and human resource constraints related to the planned assessment, but also the institutional, social, economic, spatial and environmental constraints. This early involvement is also important for ensuring the participation of these sectors in later phases of the assessment and for setting up a common understanding of the objectives and methods to be used.

The first objective to decide is whether the assessment will tackle all or some TOF subsets. This report recommends that any national TOF assessment include TOF-AGRI, trees on land under a predominantly agricultural land-use, and TOF-URB, trees on land under a predominantly urban land-use, due to their contribution to rural and urban livelihoods. The decision to include or not the TOF subsets that grow on other lands (not predominantly agricultural or urban) will mainly depend on an inter-institutional consensus regarding the relative importance of these TOF subsets in the country.

Once the contours of the assessment in terms of TOF subset coverage are clarified, the detailed objectives of the TOF assessment can be grouped into layers that will contribute to one or more of the thematic elements linked to sustainable management, in much the same way as what has been done for FRA 2010 (cf Table 2). A major decision will involve which layer(s) will be targeted in the assessment, knowing that the first layer (see below) is absolutely necessary for deriving relevant quantitative and qualitative data regarding the other layers.

The first layer consists of biophysical information on the various TOF subsets included in the assessment. This first layer itself may cover various objectives of increasing complexity, much as in forest assessments: information on tree species composition, tree spatial pattern, tree density, basal area, diameter classes distribution and tree height distribution, forms the basic set of variables needed for assessing TOF biomass, stocking volume, and carbon stock. Information may also be collected on tree regeneration, on dead and cut trees, on tree health, impacts of fire, impacts of pests and diseases, as well as on various environmental parameters that would complement the basic set of variables and allow better predictions in terms of dynamics of the tree resource, its management and planning. This first layer is extremely important as it contributes crucial information not only to the thematic element "Extent of TOF resources" (see Table 6), but also to virtually all of the thematic elements, especially through information on the characteristics and area of the various TOF systems involved in each TOF subset.

Table 6: TOF assessment layers and their links to the elements of sustainable TOF management

TOF assessment layers	Extent of TOF resources	TOF and biological diversity	TOF health and vitality	Productive functions of TOF resources	Protective functions of TOF resources	Socio-economic functions of TOF resources	Legal, policy and institutional framework
Preliminary phase: localization and area of TOF subsets	X	X	X	X	X	X	X
layer 1: Biophysical information	X	X	X	X	X	X	X
layer 2: Production and managerial information			X	X	X	X	X
layer 3: Environmental services		X	X		X	X	X
layer 4: Socio-economic functions						X	X
layer 5: Institutions and regulations							X

The second layer consists of production and managerial information that can help answer such questions as: Are TOF used? What parts are used? What are they used for? What quantities are collected annually? What are the impacts of harvesting on tree growth and on the species population dynamics? Are TOF planted or naturally regenerating, or both?

The third layer consists of complementary information related to the environmental services provided by TOF, which could help answer questions on the importance of the various TOF subsets in such services as inter alia soil fertility maintenance, erosion control, pollination, pest control, and biodiversity corridor.

The fourth layer consists of information related to the socio-economic functions of the targeted TOF subsets, information that can help answer questions such as: Are the collected TOF products sold, and if yes what is their value at different levels of the marketing chain? What is TOF contribution to the economy of households? Are tree propagating materials bought to become established as TOF? If yes, what is the value of the market (important for fruit trees planted in agricultural and urban contexts, but also for ornamental trees, especially in an urban context)?

The fifth layer consists of information on the institutional and regulatory framework related to the TOF subsets and the land on which these TOF subsets grow, such as: What is the tenure status of the land where TOF grow? What is the tenure status of the trees themselves? Are there local institutions that regulate the planting and management of TOF? If TOF products are sold, is there a taxation system?

Second phase: Translate the selected detailed objectives - sampling scheme and data collection protocols.

Now the range of detailed objectives has been tailored to the initial broad objectives. Only operational objectives have been kept for the assessment, objectives that the institutions involved perceive as reachable after considering their knowledge of the nature of the TOF subsets, as well as the human and financial resources they have secured for the assessment.

Data that can be collected by the analysis of remote-sensing images have been collected in the preliminary phase. Data to be collected now require field inventories and interviews. The detailed objectives must be translated into a set of data collection protocols. Many methods can be used for the collection of biophysical data on trees, and the same is true for data on production, uses of tree products and socio-economic functions of tree products.

A sampling scheme has to be defined. This involves many issues, such as the spatial pattern (randomly or systematically spaced), number, and form of the samples. Here also, and for almost each issue, there are a number of possible solutions. The main question in designing a sampling scheme is whether the scheme is based on landscape stratification or not; the answer leads to two main options, which respond to slightly different objectives.

✓ **Option 1.** It is possible to design a sampling scheme which takes Other Land *with TOF* into account globally. That is, the assessment focuses on the tree component outside Forest and Other Wooded Land, whatever the spatial organization of the tree component and whatever general sub-classification is used. No stratification is needed in this option, and samples may be spaced randomly or uniformly. An example is the approach used in many national forest inventories, where

samples are spaced uniformly on a grid that covers the whole country. With a good sampling design ensuring the quality and credibility of data, results in this option will be general estimates on the TOF resource, dendrometric estimates such as wood biomass or volume per ha, average species number and species composition per ha, etc. Results will also include livelihood and economic contribution estimates if the sampling includes survey questionnaires. However, this option has three main constraints that may limit its relevance:

- A very large number of field samples are required to get estimates with a reasonable precision level because Other Land *with TOF*, as a category, shows a very high heterogeneity, as noted in preceding chapters.

- It does not provide any information on the spatial distribution of TOF at the scale of the assessment, where TOF are abundant, where they are rare, where particular species grow and where they do not, etc.

- It does not provide information on the spatial patterns of TOF, which is known to be very often linked to their human context, at least in TOF-AGRI and TOF-URB.

- The two last constraints together prevent the possibility of formulating a hypothesis on the relationships between TOF and the human environment (social, economic, historical, cultural) in which they grow. In other words, this sampling option is perfectly valid for assessing and monitoring the TOF resource and its evolution with time in a purely accountability manner at the assessment scale, but it is of little use for policy and decision-making.

  The last constraint can easily be removed by integrating information on the spatial pattern of TOF and on the link between TOF and the human environment in the samples. Countries that have implemented NFMA type assessments have used this approach. This sub-option still suffers from the two first constraints, but removing the third constraint effectively raises its relevance for policy and decision making.

✓ **Option 2.** The preliminary phase, in which the country area to be sampled -Other Land *with TOF*- has been mapped by TOF subsets, introduces another interesting option: it offers the opportunity to sample each TOF subset independently instead of sampling the Other Land *with TOF* globally. The sampling scheme involves stratification. However, considering the high level of heterogeneity that characterizes the TOF subsets, the first level of stratification operated by the preliminary mapping of the four subsets may not be sufficient for covering significant differences with a non-stratified sampling scheme in terms of cost and precision. Further levels of stratification would most probably be required. Three main stratification levels could usefully be envisaged.

- The first (very classical) level involves a combination of environmental criteria, including inter alia climate, elevation, soil, and topography.

- The second level is more specific to TOF, and would involve three strata representing the three major spatial patterns encountered in TOF:

isolated trees, narrow linear tree formations, and trees in compact patches or blocks.

- The third stratification level would be specific to each TOF subset: it would consist of the major agricultural land uses for TOF-AGRI (such as industrial tree-crop, agroforest parkland, smallholder coffee plantation), the major urban land uses for TOF-URB (such as backyard garden, street, public building, public park), the nature of the associated land for narrow linear formations (such as river, canal, road, railroad), and the planted, natural or mixed origin of the patches in case of small woods. Once final stratification is decided, sampling in each stratum may be spaced either uniformly or randomly.

Note that, for a given precision level, such a detailed stratification would involve more time and effort before the field sampling phase than in a non-stratified sampling scheme, but it would reduce the time and cost of this field sampling phase. For instance, stratifying TOF-AGRI by land uses in a tropical humid country where coffee is a major product would allow distinguishing industrial coffee plantations, smallholder coffee plantations with no shade, two strata smallholder coffee plantations and coffee-based agroforests. Reflecting their degree of heterogeneity, each of these systems needs a different sampling intensity to reach the same precision level of their estimates. In contrast with a non-stratified sampling scheme, stratification allows one to adapt the sampling intensity to the heterogeneity of a given stratum. Stratification also helps avoid the risk of missing TOF categories of reduced extent but of high importance for livelihoods, such as homegardens, or for biodiversity conservation, such as narrow tree corridors.

The stratification option is probably more costly in terms of time and financial resources than non-stratification. With a good sampling design ensuring the quality and credibility of data, stratification will bear the same kind of general estimates as non-stratification. But its high degree of spatialization and its more detailed TOF-land classification allow researchers to derive credible relationships between various TOF and the human context. This ability is of prime importance for policy and decision-making.

The main choice in the design of a sampling scheme is thus between a non-stratified scheme and a stratified scheme that builds on the preliminary mapping of the TOF subsets. In the second option above, further stratification levels adapted to the TOF context and to the requested precision levels have been developed, but other sub-options are possible, which entail lower levels of stratification after the initial differentiation between the TOF subsets.

It would not make sense for this report to recommend one standard method and one sampling scheme design. Instead, this report strongly recommends that the institution in charge of the assessment rapidly forms an ad-hoc multi-sector team including people with experience and know-how in three areas: 1) the design of biophysical sampling schemes and data-collection protocols, 2) the design of socio-economic sampling schemes and data-collection protocols, and 3) the various TOF subsets and their human environment. Such a team would be in charge of designing the protocols and the

sampling scheme. Its members' collective knowledge and experience of methods and TOF contexts would ensure that the designed protocols and the sampling scheme would be operational, adapted to the TOF contexts, and efficient with regards to the detailed objectives defined for the assessment.

Whatever the sampling scheme chosen, it must be pre-evaluated by experts, including statisticians, to ensure that (1) it is feasible and it will yield credible results, (2) that it will achieve the desired allowable error estimates for the targeted current state and change estimates, (3) that analysis will permit statistically defensible assessment of uncertainty including all sources of variability (e.g., design, volume and biomass models, measurement and assessment errors), and (4) that it will permit assessment of quality assurance and control. Note that for specific TOF subsets such as scattered trees, narrow linear formations and small woods, choosing a sampling design that fulfills the above conditions is not easy and is currently the subject of active methodological research, as shown by recent publications (e.g., Baffetta et al. 2011a, 2011b, Corona et al. 2011).

Third phase: Conduct field sampling

Once the sampling schemes and sampling protocols have been defined, field sampling phase may begin. There is no fundamental difference regarding the tree variables and their estimation or measurement between field sampling in a forest inventory and in a TOF inventory, except for location (outside forests), which means that different stakeholders are involved. One of the major implications is the necessary involvement of institutions in charge of Other Land (agriculture, local administration, municipality, etc.), so that they can inform owners of the pieces of land chosen for sampling and organize access to the land. Another implication is that field sampling would benefit from being implemented by a multi-sector team.

If the assessment is not limited to the acquisition of biophysical data, then directive and/or semi-directive interviews with local stakeholders are necessary. This means that the field-sampling team would benefit from being multi-sectoral, and also from being multi-disciplinary, much as in the examples given by the countries which have used the NFMA approach.

Further phases: Data treatment, data analysis, reporting

After field sampling has been completed, the next phases resemble other assessments. It is strongly recommended to make public reports that synthesize the collected data widely available, even more so than with forest assessments, due to the wide range of stakeholders involved.

And Monitoring?

Much like what is being done for forests, repeating assessments after a few years is "a must" for monitoring TOF resources and their trends. To facilitate repeated assessments, everything that can be done to ensure an easy retrieval of the sampling plots and the interviewed stakeholders after a few years must be done: record plot coordinates, sketch map of the plot and its surroundings, note names and addresses of respondents, etc.

4.4. Recommendations for country TOF assessments

Some countries have already implemented assessments that cover most TOF subsets and include biophysical and socio-economic variables. For other countries, the recommendations below show what can be done.

Take stock of available information on TOF while designing a TOF assessment

Most countries have information available on TOF, even if they have done no TOF assessment (as noted in Chapter 3), but since this information is generally very uneven and does not cover all TOF subsets, making extraction of coherent TOF data is difficult. It is more efficient, for the many countries that do not have TOF assessments, to design TOF assessments anew on a sound basis. The flow chart above constitutes a reasonable guideline for this endeavor. It does not mean that existing information on TOF must be discarded. On the contrary, all existing information on TOF and their ecological and human context must be used in the design of the TOF assessment so that it will be operational, coherent and adapted to the TOF realities in that country.

Checking existing land-use/land cover assessment potential

One major source of information for a TOF assessment, which may be found in many countries, is a land-use/land cover assessment. This is the very basis of any assessment of natural resources, including TOF, in large areas such as countries. However, most land-use/land-cover assessments have been carried out without TOF as one of their targets, and are thus not directly usable for identifying and mapping TOF subsets and their categories. If these assessments are recent, it is certainly interesting and probably cost efficient to try to retrieve the original data and assess if it is possible to include TOF subsets in a new analysis. If that is possible, it is recommended to conduct this re-analysis and operate a stratification based on the spatial tree patterns (scattered trees, tree stands and tree lines) superimposed on the two major TOF subsets, TOF-AGRI and TOF-URB.

Think operationally, and incrementally

Current forest assessments (which cover scores of variables) did not emerge in one day and they have little in common with the first forest assessments: they are the result of decades of improvement in methods, sampling performances, field work efficiency, etc. As the review of past assessments with information on TOF (Chapter 3) shows, the TOF specific assessments that now exist should be considered the equivalent of the first forest assessments: they are the pioneer assessments for TOF.

When designing an assessment, it is thus important to think operationally and incrementally.

✓ Operationally: most countries do not have the most basic data on TOF, and the recommended target at this stage is for a national TOF assessment to be able to provide at least the following basic data, either for Other Land *with TOF* globally or for each TOF subset:

- Extent and spatial distribution;
- Estimates of the number of trees;
- Estimates of the tree biomass, timber and carbon stocks;
- Tree species composition;
- Estimates of the number of people involved in tree management.

✓ Incrementally: new layers of variables may be added later. The above basic data collected in the first assessment will allow assessing the importance of the various TOF subsets in terms of area covered, timber, carbon stocks, etc.

If judged important, it will stimulate the decision to build on this initial baseline and design a new assessment that will be useful for monitoring the TOF resources and for collecting new layers of variables.

5. Conclusions and Recommendations

There is a growing need for sound information on Trees Outside Forests (TOF) at the national level. Land-managers need clear and sound information on the resources they are responsible for, in order to manage and monitor those resources and plan related activities. This need exists at the various levels: farm, city, sub-national, national, regional, and global. International conventions and processes such as the CBD, UNFCC and the UNCCCD recently added to the need for better quantitative information on trees at national level. Important progress has been made in the assessment of forests, but the assessment of TOF is still in its infancy; in most countries the importance of the TOF resource at national level is still not based on evidence.

TOF are trees that are outside the definition of Forest. A tree may always be classified either as belonging to Forest or as a TOF; a tree cannot at the same time be a TOF and belong to Forest: TOF as a set complements Forest in the "tree realm". That means that the definition of Forest (and it varies by country) affects the contours of the TOF realm.

TOF occur in all countries. The examples based on satellite images show that TOF occur in all countries, and that they can be encountered under almost any climate where trees grow: on farms, in cities, in lowlands and mountains, in temperate and tropical regions, in wetlands and in drylands.

TOF fulfill a multitude of functions. TOF fulfill a multitude of ecological, economic, social, and cultural functions that in many cases are vital for human livelihood.

Countries need clarifications for conducting assessments of TOF. A thematic study, carried out in the framework of the FRA 2010, includes the development of an operational definition of TOF, a review of large-area assessments in relation with TOF, and a set of options for countries engaging in a TOF assessment. This report presents those options.

TOF in this report are TOF sensu FAO-FRA. As understood in this report, TOF is in the tree realm the complement of the combined two FAO categories, Forest and Other Wooded Land.

TOF includes trees and shrubs. The word "Trees" in TOF means trees and shrubs.

The TOF realm includes three TOF sets. From an analysis of FAO-FRA definitions, the TOF realm consists of three TOF sets:

1. TOF on land predominantly under agricultural land use or TOF-AGRI;

2. TOF on land predominantly under urban land use or TOF-URB;

3. TOF on land not predominantly under agriculture or urban land use or TOF-NON A/U. This set consists of 4 subsets:

- ✓ Subset 1: small tree stands (area <0.5 ha), irrespective of trees and/or shrubs spatial organization, height and canopy cover level;
- ✓ Subset 2: linear tree formations, narrow (width < 20 m), irrespective of area, plant height and canopy cover level;
- ✓ Subset 3: large stands (area ≥ 0.5 ha), trees (height ≥ 5 m) with low canopy cover level (cc < 5 percent);

✓ Subset 4: large stands (area ≥ 0.5 ha), shrubs (height <5 m) or a mixed cover of shrubs and trees) with low canopy cover level (cc < 10 percent).

Other Land includes two sub-categories: with TOF and *with No TOF*. In the FAO-FRA land classificatory framework, Other Land, in the land realm, complements these combined sets: Forest, Other Wooded Land, and Inland Water. Depending on the presence or absence of trees, Other Land may be subdivided in two mutually exclusive sub-categories.

Minimum threshold values are needed for sub-categories to be operational. This report proposes the following minimum threshold values:

✓ Canopy cover: 5 percent if trees only; 10 percent if combined trees and shrubs
✓ Area: 0.05 ha
✓ Tree line length: 25 m
✓ Tree line width: 3 m

These minimum thresholds result in operational definitions. Based on the presence of TOF at threshold levels, the two Other Land sub-categories are:

✓ Other Land *with TOF* (OL*wTOF*)
✓ Other Land *with No TOF* (OL*wNoTOF*)

Most TOF are included in Other land *with TOF*; by using the minimum thresholds values, some TOF may occur in Other Land *with No TOF*.

Other Land *with TOF* (OL*wTOF*) consists of three sets:

OL*wTOF*-AGRI: includes all lands predominantly under agricultural land use with trees and/or shrubs, whatever their spatial pattern (in line, in stands, scattered), provided that the area is ≥ 0.05 ha, the canopy cover is ≥ 5 percent if only trees are present, or ≥ 10 percent in case of combined trees and shrubs, the width ≥ 3 m and the length ≥ 25 m for linear tree formations.

OL*wTOF*-URB: includes all lands predominantly under an urban use with trees and/or shrubs whatever their spatial pattern (in line, in stands, scattered), provided that the area is ≥ 0.05 ha, the canopy cover is ≥ 5 percent if only trees are present, or ≥ 10 percent in case of combined trees and shrubs, the width ≥ 3 m, and the length ≥ 25 m m in case of linear tree formations.

OL*wTOF*-NON A/U: includes all lands not predominantly under agriculture or urban land use that cannot be classified as Forest or as Other Wooded Land, when the thresholds for Other Land *with TOF* are met. It includes two subsets:

- Subset 1: small tree stands (0.05 ≤ area < 0.5 ha) with canopy cover ≥ 5 percent if trees are present, or ≥ 10 percent in case of combined trees and shrubs.

- Subset 2: linear tree formations, Narrow (3 m ≤ width < 20 m), with length ≥ 25 m, and canopy cover ≥ 5 percent if trees are present, or ≥ 10 percent in case of combined trees and shrubs.

TOF assessments involve a large range of stakeholders. The three TOF sets correspond to a large variety of stakeholders: farmers, pastoralists and institutions linked to agriculture and rural development; people living in settlements and cities and institutions linked to urban management and development; environmental organizations, rural and urban planning institutions. It is very important to take this variety of stakeholders into account when assessing TOF.

Some ambiguities remain. Even with the proposed rigorous land classificatory framework, some ambiguities related to current FAO-FRA definitions remain for classifying some lands. These ambiguities concern the following terms and concepts:

- ✓ Agricultural land-use
- ✓ Urban land-use
- ✓ Shifting cultivation
- ✓ Rubber plantations
- ✓ Linear tree formations
- ✓ Agroforestry.

The Review of TOF assessments in Chapter 3 showed that TOF assessment at large scale is still in its infancy.

Recent progress has been made:

- ✓ One global scale TOF assessment has been realised (Trees on Farm, 2009). It concerns TOF on agricultural land, and its results provide a rough approximation of the global extent of this set: approximately 10 million km² (or 46% of total "agriculture land") have more than 10% tree cover.
- ✓ A regional scale assessment included in this review (Europe - Corine Land Cover) does not specifically focus on TOF but includes land-use/land-cover classes that are TOF specific, allowing their spatial distribution and extent to be assessed.
- ✓ Countries that have implemented the NFMA approach have successfully integrated TOF and TOF issues into their national forest (and tree) assessments. These countries may provide convincing estimates of the variables related to TOF resources. Their precision could be enhanced with increased sampling intensity.
- ✓ Many countries have available national assessments that may provide (in some cases after data re-analysis) information on TOF sets. It is possible for those countries to build on these assessments and develop complementary assessments that would, at a lower cost than if no data were available, help in getting a more complete, reliable and accurate picture of their TOF resource. In particular, land-cover/land-use assessments constitute a perfect starting point, provided the land-cover classes have been judiciously defined so that they unequivocally cover TOF categories.
- ✓ Some countries have implemented assessments of their tree and forest resource that are so detailed that they may be used for providing estimates of the main biophysical variables related to TOF. A few other countries have undertaken specific TOF assessments with a focus on a TOF set. These TOF-specific assessments can be combined, and complemented if necessary with new assessments, to allow a quite complete, reliable and accurate picture of their national TOF situation. These cases show that assessing TOF at national scale is possible, with no insurmountable technical or methodological obstacles, as long as the TOF categories are consistent and the assessments organized in a complementary way.

Keys for TOF assessments (Chapter 4) are recognition that:

Assessing TOF is conceptually similar to assessing trees in forest. As in forest assessments, low- and high-resolution remote-sensing images help to identify land with TOF; sampling for inventory proceeds the same way as for forests. Field inventory protocols and survey questionnaires are similar to those used for forest. Sampling, field inventory protocols and survey questionnaires could require adaptation to the specificities of targeted TOF subsets (just as they could need to be adapted to specific forest types).

A prerequisite is acknowledging the range of land-uses that include TOF. The TOF realm includes small woods and linear tree formations when land-use is neither urban nor agricultural. It also includes trees on farms and trees in cities. Any TOF assessment should thus take into account the heterogeneity of the TOF realm at the onset. This helps to identify the sectors that are legitimately involved in the other TOF sets (environment, agriculture, rural development, transportation, city planning, etc.). This can lead to setting up an ad-hoc multi-sector, multidisciplinary team in charge inter alia of refining the detailed objectives of the assessment, as well as identifying the protocols and sampling schemes.

Credible results depend on sound protocols and sampling schemes. Protocols and sampling scheme must be pre-evaluated by statisticians to ensure that they will (1) yield credible results, (2) achieve the desired allowable error estimates, (3) permit statistically defensible assessment of uncertainty, and (4) permit assessment of quality assurance and control.

Pioneer national TOF assessments provide useful models. Pioneer TOF assessments (Chapter 3) offer an important source of inspiration, much as pioneer national forest assessments did. Adaptation to national targets and to country ecological, social and economic situation, are required, keeping in mind that different methods provide different kinds of results (for instance, LCCS may provide maps of the various Other Land *with TOF* sets, while NFMA type assessments may provide reasonable estimates of Other land *with TOF* extent, TOF number, volume, and carbon.).

Recommendations

The following four major recommendations start with a recommendation on national TOF assessments and proceed to other recommendations focused on the international situation and an eventual global TOF assessment, modeled on the global forest resources assessment, and the role of FAO's FRA programme.

Countries should now carry out their national TOF assessments. It is now technically possible to design and implement sound national TOF assessments using the practical keys in this report. Countries that need assistance and guidance in realizing their assessment can now look for support from the international community. If the political will exists, a country can assess its TOF resource.

Clarify FAO-FRA position regarding global TOF assessments. National forest services are often not in the best position to implement national TOF assessments by themselves, because their mandate for two major TOF sets is questionable (land predominantly under agricultural use, and land predominantly under urban use). Agencies in other sectors such as agriculture, environment and urban development should be associated to TOF assessments from the outset. On the other hand, national TOF assessments cannot be implemented without foresters because of their expertise in assessing trees.

The situation is the same at the international level: a global TOF assessment should reflect the variety of TOF and involve a range of international programmes: those dealing with forest, agriculture, environmental and urban issues. At FAO, the Agriculture and Consumer Protection department compiles national statistics on the major non-timber tree crops (which are TOF), but the FRA programme of the Forest department is currently the only international programme that explicitly compiles national information on TOF (extent of Other Land With tree Cover).

In view of the low response rate of countries in the last two Global Forest Resources Assessments, another international effort could be proposed to improve the international reporting of TOF. Two options may be envisaged: (1) The FRA programme sets up an ad-hoc, multi-sector committee in charge of TOF national reporting, (2) FAO sets up a new ad-hoc TOF Resources Assessment programme including experts from the relevant departments.

These two options may also be combined with the initial multi-sector committee under the FRA programme, becoming an independent programme once national and international TOF assessments reach a certain level.

Take action for FRA 2015. In whatever way the FAO FRA programme proceeds in the coming years, it is very important that the efforts already done to integrate information on TOF in the regular assessments of global forest resources be continued in FRA 2015, for two main reasons:

- ✓ FAO-FRA is currently the only legitimate international programme able to gather national information on TOF in a coordinated manner;
- ✓ Before leaving the issue of TOF assessment to another setting, FAO-FRA should still refine the definition of a few terms so that the frontier between Forest, Other Wooded Land, and Other Land *with TOF* can always be objectively defined in practice. This is urgently needed because the current situation may in a number of countries spell some doubts on the forest data reported in the last global forest assessments.

This report thus recommends three technical improvements for implementation in FRA 2015:

✓ Reduce subjectivity in national reporting to FAO-FRA: Improve the definitions[1]. This involves minor modifications of the existing definitions, and defining the terms that allow subjectivity in classifying lands, by:

- Reversing the order of presentation of the land-use and the land-cover criteria in the definitions of Forest, Other Wooded Land and Other Land With Tree Cover. This will help countries better realize the importance of the land-use criterion in these definitions and improve their reporting;
- Defining "agricultural use" and "urban use" in the definitions of Forest, Other Wooded Land and Other Land With Tree Cover, to help countries report in a much more objective and homogeneous way;
- Qualifying the term "abandoned shifting cultivation" in the definition of Forest, so that the sequential nature (crop-fallow cycles) of this agricultural system is respected.

✓ Improve country reporting on the extent of Other Land With Tree Cover (OLWTC)[2]. An analysis of country reporting to FRA 2010 on the extent of OLWTC showed that only a few countries can, at this stage, contribute relevant and relatively precise data to a global TOF assessment on more than the most basic variables. Rather than adding new variables to better qualify OLwTC, it seems more efficient to ensure a much better response from countries on the extent of OLwTC. In addition to improving the definitions (see above), national agricultural and urban services should be involved early, and a few modifications should be made in the Guidelines for Country Reporting.

✓ Develop a global TOF assessment in the FAO FRA Remote Sensing Survey. The FRA Remote Sensing Survey has been instrumental in improving the quality and consistency of regional and global data on the extent of forests. High-resolution images now allow, in most cases, the identification of TOF subsets from the air. A pilot study should build on the Global FRA Remote Sensing Survey and on the RSS data already available to do a first approximation of a global estimate of TOF. That such pilot study should aim to provide regional and global estimates of (1) Other Land With Tree Cover (OLWTC: agriculture AND urban) and (2) Other TOF subsets: small woods and narrow tree lines.

1 A more detailed list has been provided to FAO-FRA at the Expert Consultation on "Long-Term Strategy for Global Forest Resource Assessment", Nastola, Finland, 13-15 September 2011.

2 A detailed list of modifications in the Guidelines for Country Reporting has also been provided to FAO-FRA at the expert consultation in Nastola (2011).

Set the goal and adopt a way forward for global TOF assessment. With a more long-term perspective and in view of the growing importance of TOF issues globally, it is necessary to define clear objectives for a global TOF assessment, much like what has been done for the global assessment of forest resources. This is important to stimulate the implementation of sound national TOF assessments. The programme in charge of TOF at FAO should soon organize an expert consultation meeting to:

- ✓ Finalize the 7 themes proposed in this report as a basis for developing a global TOF resources assessment framework (extent of TOF resources; TOF biological diversity; TOF health and vitality; productive functions of TOF resources; protective functions of TOF resources; socio-economic functions of land with TOF; and legal, policy and institutional framework)
- ✓ Set up a step-by-step agenda with realistic targets for further global TOF resources assessments, on the basis of the finalized framework.

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