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Existing Vegetation Classification, Mapping, and Inventory Technical Guide: A New National Monitoring Strategy for the United States Forest Service

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Abstract

The US Department of Agriculture Forest Service (USFS) has recently released the Existing Vegetation Classification, Mapping, and Inventory Technical Guide, a document intended to provide guidance to agency staff that develop existing vegetation classification, map, and inventory data and information products. This technical guide is based on a conceptual framework that highlights the relationships between vegetation classification, mapping, and inventory processes, and provides guidance for implementation of these activities. It identifies agency business needs, lists agency guidelines and requirements, and provides a survey of state-of-the-art methods and the theory behind them.

This paper describes the technical guide and explores the conceptual framework for international inventory and monitoring applications, such as for Reducing Emissions from Deforestation and Forest Degradation (REDD).

Keywords: Forest monitoring systems, Vegetation classifications, Vegetation maps, Vegetation inventory, Land cover, Land use, REDD+

Introduction, scope and main objectives

The US Department of Agriculture Forest Service (USFS) manages the 78 million-hectare National Forest System that represents a variety of landscapes and ecosystems across the US. The USFS also conducts research with and provides international assistance to a wide variety of stakeholders through its Research and Development and International Programs (IP) divisions. The US national forest inventory is a research effort conducted by the Forest Inventory and Analysis (FIA) program and its inventory and monitoring expertise is shared internationally by IP. Classification, mapping, and inventory of existing vegetation are fundamental to the stewardship, conservation, and appropriate use of forests and grasslands within the United States and those countries supported by Forest Service programs.

The USFS has recently released the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson *et al.* 2015) to provide guidance for developing existing vegetation classification, map, and inventory data and information products that 1) comply with federal and agency standards, 2) are consistent and continuous across the landscape, and 3) are responsive to the evolving business needs of the USFS and its conservation partners.

FIA's National Inventory and Monitoring Applications Center (NIMAC), a group of inventory techniques specialists, and the Remote Sensing Applications Center (RSAC), a group of remote sensing techniques specialists, have accumulated many decades of experience in the classification, mapping, and inventory of vegetation in the US. Technical specialists from these centers are often asked by Forest Service leadership to share some of this accumulated knowledge with partner countries. NIMAC and RSAC work closely with the SilvaCarbon program (www.silvacarbon.org), a consortium of US government agencies and partners that conduct capacity building and science activities with countries interested in developing or improving systems for monitoring terrestrial carbon. Activities include informal consultations, formal trainings, workshop participation and science partnerships. Many of the same technical specialists involved in these international activities contributed to the development of the technical guide and the basic principles and methods can readily be shared with partner countries.

The goal of the current paper is to describe the technical guide and explore the conceptual framework for international inventory and monitoring applications, such as for Reducing Emissions from Deforestation and Forest Degradation (REDD).

Methodology / approach

Understanding the technical guide and its role as a new national monitoring strategy requires answering three basic questions.

What is Existing vegetation? As defined in the scientific literature and used in the Technical Guide, existing vegetation is defined as the plant cover, or floristic composition and vegetation structure, occurring at a given location, at the current time.

Why is existing vegetation information important? Existing vegetation is the primary natural resource at the heart of nearly every management decision made by the Forest Service. Existing vegetation represents more than traditional information about the agency's timber supply and carbon stocks. It is also used to understand the extent and distribution of habitats for terrestrial species as well as potential fuel for wildland fires that may put communities and other resources at risk. As a result it has become the highest priority and largest total annual investment for agency inventories and assessments.

As with any data or information product, managers are concerned with limitations of the data, especially with requirements to use "best available science and information". That leads to the last basic question we will address. **What are today's key limitations to existing vegetation information products?**

The Forest Service has a long history of classification, mapping, and inventory of existing vegetation based on local, regional and national information needs. As a result, legacy methods and systems lacked consistent methodology and standards. Information was not comparable across Forest Service administrative unit boundaries and not consistent with information developed by other conservation partners. This situation was an ineffective way to promote collaborative landscape conservation that responds to rapidly evolving business needs and issues, especially those that span complex landscapes.

Historically, the Forest Service has placed a high value on vegetation and land cover maps, particularly when they were integrated with inventory data. Establishment Reports for the Forest Reserves contained maps and tabular estimates of timber volume classes. For example, H.B. Ayers (1899) produced maps of the Lewis and Clark Forest Reserve in Montana (figure 1). These maps were based on ocular estimates of fairly large map feature delineations and represented years of field reconnaissance. The tabular reports were generated based on areas represented by different map units. These 1899 products represented the first maps and inventory estimates of forest condition for the Forest Reserves that would later become the National Forest System.

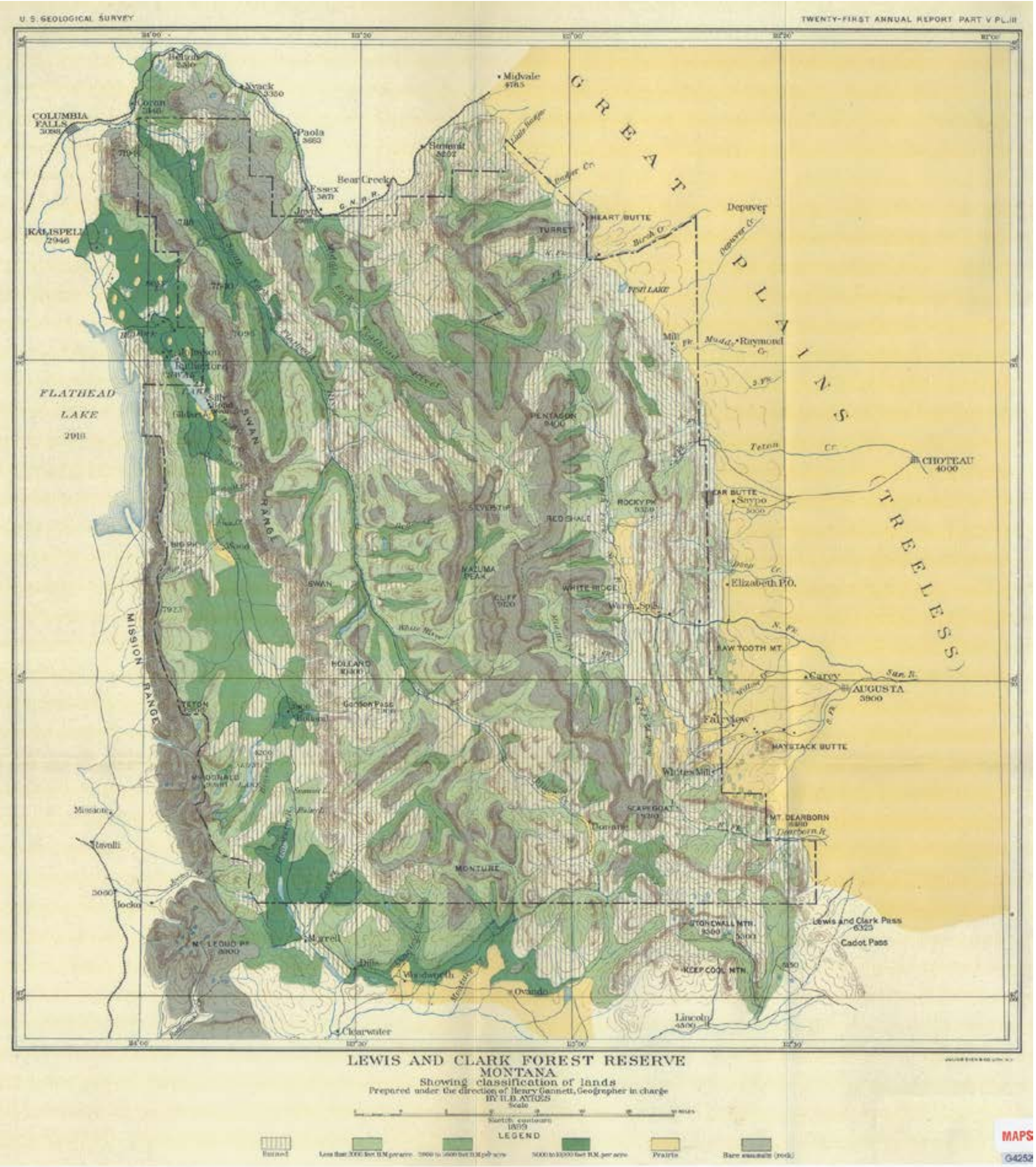

Fig. 1:Lewis and Clark Forest Reserve in western Montana ca. 1899: H.B. Ayres (Nelson *et al.* 2015).

Once the National Forest System was established, the primary issues facing forest managers in the western US were timber trespass and timber management. As a result, early efforts focused on describing forest types and volume class mapping. As business needs such as the acquisition and establishment of National Forests in the eastern US evolved, more complex classifications were developed, and information products like maps and reports reflected expanded local forest-level needs. More people also became involved and began relying on this information, leading to a plethora of local and regional methods and standards.

Today's Forest Service leaders and program specialists face a myriad of evolving challenges that must be addressed at multiple scales, requiring collaboration with a diverse set of landscape conservation partners. Similar challenges are faced by natural resource managers throughout the world.

The technical guide serves as a standard framework that provides guidance for matching the information needs with the appropriate information products. The guide addresses products generated at four spatial levels or scales:

National-level information products are intended to support nationwide or international information needs. Products at this level may be developed programmatically (like the National Land Cover Database [NLCD] tree canopy cover layer) or, when feasible, aggregated from existing lower level products. They contain the coarsest thematic detail, spatial resolution, and accuracy of the four types of products.

Broad-level information products are intended to support State, multistate, or regional information needs. Products at this level may be developed programmatically or aggregated from existing mid-level products, when feasible. Information is continuous across the area of interest with consistent thematic classes, spatial resolution, and known accuracy. Like the national-level, these data products require a relatively low cost/hectare investment to develop.

Mid-level information products are intended to support Forest or multi-Forest information needs. Products at this level are typically developed programmatically from remotely sensed data, and often integrate standard base-level products where they exist.

Base-level products support Forest and District information needs and represent the highest thematic detail, spatial resolution, and accuracy. Base-level information is only available for limited, scattered areas because of the high cost of development. Products at this level are typically developed from large-scale, remotely sensed data like aerial photographs, high resolution satellite imagery, and field inventory data.

The Technical Guide addresses three distinct, but related activities that provide basic vegetation information products to support Forest Service decision making – vegetation classification, mapping, and inventory (Brewer *et al*. 2006). These three activities and the relationships among them form the conceptual framework for the new Forest Service monitoring strategy (figure 2).

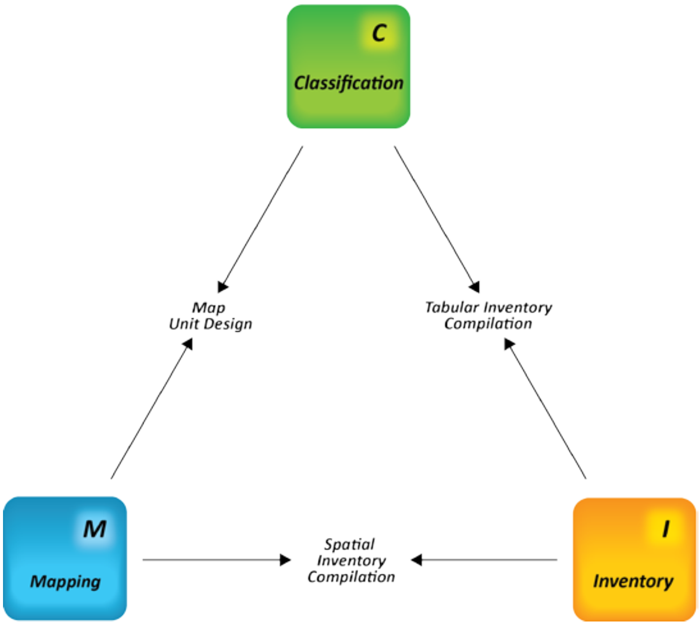

Fig. 2: Relationship of vegetation classification, mapping, and inventory. The corners of the triangle represent classification, mapping, and inventory activities, while the sides of the triangle represent the major process relationships that provide feedback and integration (Nelson *et al.* 2015).

Vegetation classification is the grouping of similar entities into named types or classes based on shared characteristics. Classification answers the question, "What is it?" The purpose of the classification protocol described in the Technical Guide is to enable the consistent classification of existing vegetation across National Forest System lands and achieve compliance with the US Federal Geographic Data Committee (FGDC) standards by including elements from the US National

Vegetation Classification (NVC) system. FGDC and NVC are federal standards created to foster consistency among agencies. As illustrated in figure 3, vegetation classification is a complex two-staged process requiring considerable time and expertise to complete.

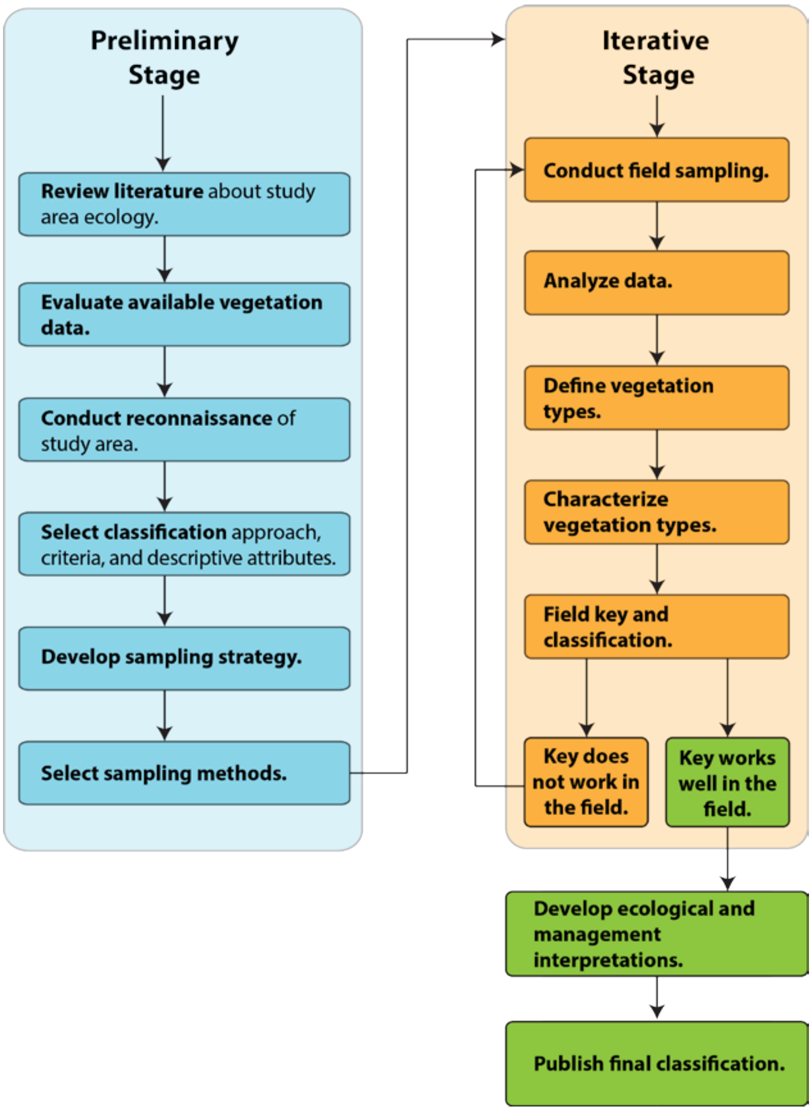

Fig. 3: Existing vegetation classification process diagram (Nelson *et al.* 2015).

The classification protocol provides guidelines for collection, analysis, and interpretation of data used to classify and describe associations, alliances, and dominance types based on floristic data. The current FGDC standard requires that any vegetation classification system used by a U.S. federal agency must be able to crosswalk to the NVC. A similar requirement would apply to crosswalking detailed vegetation classifications to the land-use and land-cover categories required for greenhouse gas inventory reporting by the Inter-governmental Panel on Climate Change (IPCC 2006).

Vegetation mapping is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Mapping answers the question, "Where is it?" The mapping protocol provides guidelines for developing consistent and continuous existing vegetation map products addressing this question. The protocol covers mapping at all four geographic scales described above. Guidelines for map project planning and implementation and for map data storage, delivery, and updating are also addressed. Methods presented in the guide are illustrated in the process diagram in figure 4.

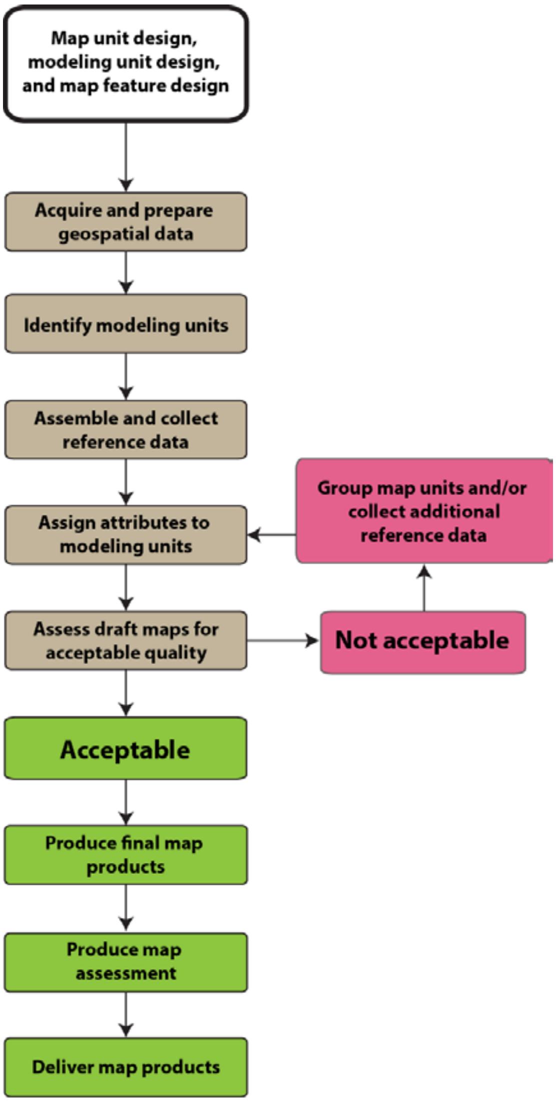

Fig. 4: Existing vegetation mapping process diagram (Nelson *et al.* 2015).

Implementing these guidelines allows for compatibility and consistency of existing vegetation maps across different map project areas and map levels. The resulting existing vegetation maps provide the foundation for consistent, science-based management decisions. These guidelines would be particularly useful for countries where land cover and land use mapping is accomplished by several departments or agencies, particularly when they are not in the same ministry. As with classification, the most cost-effective and appropriate mapping methods needed to meet agency business needs must meet the needs of resource managers and policy makers.

Vegetation inventory is the process of applying an objective set of sampling methods to quantify the amount, composition, and condition of vegetation within specified limits of statistical precision. Inventory answers the question, "How much is there?" The purpose of the inventory protocol is to provide guidance on how to assess existing vegetation inventories to meet project business needs and, if needed, how to design and implement a new vegetation inventory. As illustrated in figure 5, this protocol provides guidelines for processing and interpreting inventory data and for evaluating and adapting protocols to meet information needs related to the "How much is there?" question.

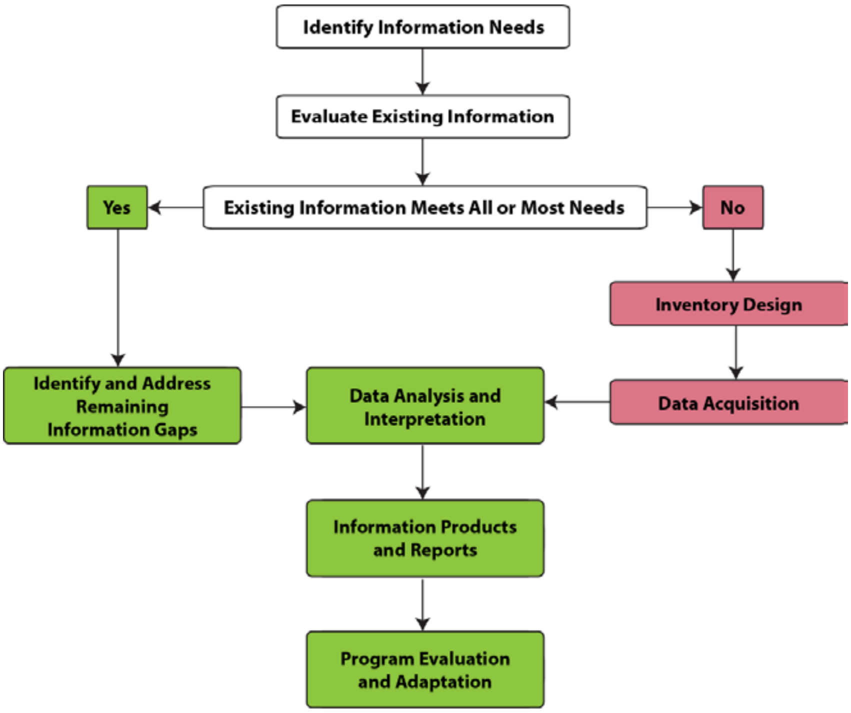

Fig. 5: Existing vegetation inventory process diagram (Nelson *et al.* 2015).

This section of the technical guide also includes information about existing inventories, Forest Service corporate protocols, and associated databases that are available to collect, warehouse, analyse, and understand the current condition of existing vegetation. It also includes an overview of design-based, probabilistic inventories and discusses how they can be integrated with classification and mapping.

These three activities and the associated technical guide protocols have some key relationships illustrated in the conceptual framework (figure 1) that are important to improving and integrating the results. They can also be used as a framework for establishing relationships among data products for REDD+ reporting, which often include some combination of vegetation classifications, maps and inventory data. The primary process relationships include the following:

> **Tabular Inventory Compilation** is the process used to compile an unbiased quantification of the composition of vegetation to summarize and quantify vegetation characteristics for each vegetation class within the area of interest. This is a key process for identifying classes to include in mapping projects and for obtaining area estimates to compare to mapping results.
>
> **Map Unit Design** is the process of establishing the relationship between vegetation classification units and mapping units depicting them within the area of interest. This is a key process for designing map units that are: exhaustive, mutually exclusive, field applicable, ecologically relevant, and technically and logistically feasible.
>
> **Spatial Inventory Compilation** involves the intersection of inventory data with map products. It allows the use of map information as classification (or domain) variables allowing the inventory data to be summarized and to quantify vegetation characteristics for each map class. This is particularly useful for vegetation characteristics that are not mapped directly.

Integrating classifications, maps, and inventories utilizing these three primary process relationships is essential for maintaining consistency and continuity among the different data and information products. For example, map-based area estimates of vegetation and land cover types should be consistent with design-based inventory estimates of the same vegetation and land cover types for the same area of interest. These primary process relationships are also essential for producing high quality data products. For example, map units that are designed without consideration of the vegetation classification units may produce accurate maps, but have limited utility for describing conditions relative to vegetation classes. Conversely, a map unit design process that does not consider the mapping feasibility of the map units will generally produce poor quality maps of low accuracy.

For the complete technical guide publication, training modules, and reference materials consult the project website at: http://www.fs.fed.us/emc/rig/protocols/vegclassmapinv.shtml

Discussion

Existing vegetation is the primary natural resource at the heart of nearly every management decision made by the Forest Service and is the primary interest of the agency's conservation partners. While the Forest Service has a long history of classification, mapping, and inventory of existing vegetation these efforts have been based on mostly local and regional information needs. As a result, legacy methods and systems lacked consistent methodology and standards and the resulting data products were ineffective in addressing national and sub-national resource issues. This problem was particularly difficult when sharing data with conservation partners from other agencies or departments. To help address these issues, the Existing Vegetation Classification, Mapping, and Inventory Technical Guide provides guidance for developing existing vegetation classification, map, and inventory data and information products using core principles and standard guidelines.

Many countries throughout the world are developing classifications, maps, and inventories to meet local or regional information needs. In some cases data are being developed to address the needs of a particular program such as REDD+ without considering other broader, longer term information needs such as monitoring for sustainable forest management. The experience of the Forest Service and the conceptual framework presented in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide could assist countries in developing an efficient and effective classification, mapping, and inventory system that meets multiple objectives.

The Forest Service is committed to implementing this technical guidance and is developing training modules for technical aspects of the guidance. A GIS data dictionary and an associated database have also been developed. Concurrent with these developments is the production of the Design and Analysis Toolkit for Inventory and Monitoring (DATIM), a web-based toolkit for planning inventories and for analysing the results. A PC version of the Design Tool for Inventory and Monitoring (DTIM) has been used extensively with partner countries through the SilvaCarbon program and is available for use in Spanish and English (Scott *et al.* 2009).

Conclusions / outlook

The experience gained in the past 100 years by the US Forest Service is reflected in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide. Partner countries can benefit from the Forest Service experience and improve the efficiency and effectiveness of their programs. Substantial investments are being made in mapping and/or inventory efforts associated with REDD+ activities. These activities are sometimes conducted without regard for the broader information needs of a comprehensive land cover and land use monitoring system and a national forest inventory. As a result the REDD+ data products may not meet these broader information needs and usually cannot be integrated with existing sub-national data. The technical guidance, training material, and data structures associated with the Existing Vegetation Technical Guide and with the Design Tool for Inventory and Monitoring can assist partner countries in assessing their broader information needs and designing a system to address those needs.

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