Terrestrial Productivity Analysis Potential

Preface

This report was prepared for the Ecosystem Characterization and Monitoring Initiative (ECMI) sponsored by the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP). This report was written by Dr. L. Jean O'Neil, Ms. Amy Lee, and Dr. David Price, Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC). Project Manager for the ECMI is Dr. David Tazik, EL, ERDC, Vicksburg, MS. Program Manager for the SEMP is Dr. Harold Balbach, Construction Engineering Research Laboratory (CERL), ERDC, Champaign, IL.

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1 Purpose of the Paper

This white paper was commissioned to investigate the question of whether or not sufficient data are being collected at Fort Benning, GA to analyze terrestrial system productivity. A review of methods for analyzing productivity and data collected on Fort Benning via their forest inventory protocol, the SERDP Ecosystem Management Program (SEMP), and other sources was undertaken. The objective of this review is to determine whether or not these methods and data will lead to an understanding of terrestrial system productivity at Fort Benning.

The paper begins with background pertaining to terrestrial productivity efforts at the national scale as well as applications specific to Fort Benning. Next, a description of methods for calculating terrestrial productivity is provided. In this chapter, techniques for calculating gross primary productivity (GPP), net primary productivity (NPP), and woody productivity (WP) are discussed. The following chapter summarizes past, present, and future data collection efforts at Fort Benning. Calculating Productivity is a discussion of those models best suited to Fort Benning's needs and available data. The paper concludes with a discussion of concerns regarding the efficacy of data and its application in productivity models including: spatial and temporal concerns, resolution, reliability, redundancy, and transportability.

2 Background

There is long-term merit in establishing a productivity dataset at Fort Benning, GA. With increased national and international interest in productivity measurements, analysis of carbon fluxes, and related global concerns, it can be argued that there is a stewardship requirement to understand how Fort Benning fits into a larger context. Georgia plays a significant role in primary production. The state, along with five others, accounts for over a third of the forest biomass of 33 eastern states (Brown et al. 1999). Using data collected on the installation, researchers can describe how Fort Benning contributes to the overall ecosystem health of the region and nation. Additionally, data collected at Fort Benning can contribute national monitoring programs such as Forest Health Monitoring (FHM), Forest Inventory and Analysis (FIA), and the North American Carbon Program (NACP) (Wofsy and Harriss 2002).

Cornforth (1999) stated that sustainable land management is one of five key indicators concerned with maintaining and enhancing productivity. His comments were written in a national and global context; however, his concerns regarding sustainability are some of the same concerns that exist at Fort Benning, e.g., soil quality and pest infestations. Changes in functions such as productivity can also provide an indication of the "onset of ecosystem stress," according to Cairns et al. (1993) in a proposed framework for developing indicators of ecosystem health, and an indication of ecosystem dysfunction (Whitford et al. 1999).

Several long-term and large-scale programs measure or deal with some aspect of terrestrial productivity. The major programs potentially relevant to ECMI are listed in Table 1.

Table 1. Programs that collect or use data on terrestrial productivity

Responsible Element	Program	Purpose	Productivity measurement
Environmental Protection Agency (EPA)	Environmental Monitoring and Assessment Program (EMAP)	Develop the tools to monitor and assess the status and trends of national ecological resources	Historical Normalized Difference Vegetation Index (NVDI) values used in Mid-Atlantic to describe relative greenness of cells, i.e., forest cover
Food and Agriculture Organization of the United Nations	Global Terrestrial Observing System (GTOS), GT-Net	Provide policy makers, managers, and researchers with data on terrestrial ecosystems relative to sustainable development	Demonstration project of GT-Net is to "improve current estimates of global terrestrial primary productivity," in the United States, working on selected LTER sites
Forest Service, U.S. Department of Agriculture	Forest Health Monitoring (FHM) Forest Inventory and Analysis (FIA)	Monitor health of forested systems, because of their importance in carbon flux and in production of food and fiber	Indicators of health, e.g., productivity and vitality, as they relate to landscape metrics
U.S. Global Change Research Program, a 10-agency partnership (USGCRP)	North American Carbon Program (NACP)	Develop knowledge of carbon stock and accounting; to increase our ability to cope with climate variability and change	Multiple formats, using carbon inventories, remote sensing, and models
National Aeronautics and Space Administration (NASA)	Earth Observing System (EOS), with the instrument MODIS	Provide data to run models of carbon flux, carbon dioxide accumulation, and global climate	Net photosynthesis, annual net primary productivity, and several interim parameters

Table 1. Programs that collect or use data on terrestrial productivity

Responsible Element	Program	Purpose	Productivity measurement
		change	
National Science Foundation	Long-Term Ecological Research (LTER) sites	Conduct long-term research on the pattern and control of primary production	Primary production in multiple ecosystems and locations
The Heinz Center	Database and reporting process	Collect and present data on current status of US forests, croplands, and coasts and oceans	Plant growth and primary productivity

Use of this Information at Fort Benning

Fort Benning in the context of national programs

The USDA FIA and FHM programs were designed to track a large number of individual trees over time. Repeated visits to the same location are made for trend analysis. Compilation of data on individual trees allows various stand analyses, such as productivity. The FHM program monitors several indicators, including tree crown condition, coarse woody debris, tree growth, fuel loading, tree regeneration, plant diversity, tree damage, vegetation structure, tree mortality, and soils. Each indicator is associated with specific data collection protocol; for example, tree crown condition is described by eight measurements. The ECMI has selected forest characterization elements to either directly provide or to allow calculations related to these indicators.

MODIS from NASA provides Photosynthesis (PSN) and NPP algorithms. These vegetation production programs provide regular measures of terrestrial vegetation growth. Production is determined by computing a daily net photosynthesis value that is then composited over an eight-day interval. The composite observations are annualized to generate NPP values. The University of Montana is lead in the development of these algorithms and will make them available in 2002. MODIS data are being collected for Fort Benning. Remote sensing information is a major contributor to the NACP, and data from Fort Benning can contribute to filling knowledge gaps of carbon stock.

Fort Benning management

There is also shorter-term and more easily visible merit to some specific metrics on productivity, both to the installation and to the SEMP researchers. Changes in biomass from one period to another, obtained during measurement of productivity, may show an effect related to land management, i.e., the effectiveness of prescribed burning. Observations and measurements of trees, as major biomass and structural components, are valuable in providing information on timber production, wildlife habitat, land management rehabilitation progress, and other aspects of land stewardship and natural resources management.

In addition to ECMI objectives, these data have utility in other applications. Habitat Suitability Index models commonly contain a tree variable, e.g., tree diameter, size of cavity trees, occurrence of mast producers, or den sites. Another ecosystem assessment tool that uses ECMI data is the Ecological Dynamics Simulation (EDYS) program (Childress et al. 1999). In applying EDYS, plant parameters are key metrics for calculating complex ecological dynamics across varied spatial scales. Additionally, ECMI data can be readily utilized by a number of physiologically based forest productivity models such as PnET.

As our knowledge of biotic relationships increases, long-term data, such as that collected by ECMI, will be more valuable. For example, Eberhardt (2000) found that yellow-bellied sapsuckers selected trees based on species and characteristics that could be described in an index of tree health. Additional conditions can be reported for special interest communities. Data on individual tree spacing and size in a longleaf pine stand allows its tracking with stand maturity. For example, Landers and Boyer (1999) described the physical condition of old-growth stands. Those descriptions included stand density, basal area, age, diameter, standing snags, and downed logs. They noted indicators of old-growth status in longleaf pines included the point at which height growth ends. Old-growth longleaf pines can be identified by a "gnarled, flat top morphology, a slightly widened trunk base, or the presence of RCW cavities" (Harper et al. 1997). Data for management of red-cockaded woodpeckers includes species composition (species of pines and presence of hardwoods), tree diameter, and tree height. A management tool for red-cockaded woodpeckers would include areas that are attaining old-growth status.

3 Terrestrial Productivity

All biological organisms require matter for their construction and energy for their activities. This is not only true for individual organisms but for populations and communities as well. Energy is provided by the sun via photosynthesis, the mediating process, capturing its energy and making it available for organisms. Assimilation of matter occurs during respiration. When describing photosynthesis and respiration that occur in a community, we describe the activity per unit area. It is within this area that vital metrics such as light, water, and nutrients are found, enabling the processes of photosynthesis and respiration to occur.

In describing the life of a community, we use the term “primary productivity” to identify that rate at which biomass is produced per unit area by plants, the primary producers. The total fixation of energy by photosynthesis is referred to as gross primary productivity (GPP). The plants themselves require energy for growth and life functions. Therefore, some of the energy they produce is consumed and lost to the community in the form of respiratory heat (R). The difference between GPP and R is known as NPP and represents the actual rate of production of new biomass that is available to other organisms.

Global terrestrial NPP is estimated to be 110-120 x 10^9 tones dry weight per year (Begon et al. 1996). Production of this energy is not uniformly distributed across the globe. In forest biomes there is a trend of increasing productivity from boreal, to temperate, to tropical regions (Schlesinger 1997). This latitudinal change suggests that radiation and temperature are limiting factors. Other factors can restrict productivity as well. Some of these factors are water, essential mineral nutrients, soils, and canopy cover. Rayamajhi (1996) in a study of long leaf pine in the southeast, showed that climatic data are necessary to evaluate productivity over time.

There are several approaches for measuring primary productivity. One method is calculating the difference between net photosynthetic rate and respiration rate. The harvest technique is based on harvesting all plants from a sample plot and is appropriate for simple communities of short-lived plants. Forest and shrub land productivity techniques are based on more complex measurements of growth of different tissues in trees and other plants. These methods rely on allometric equations that relate plant growth to plant size. Gas-exchange techniques measure the flux of CO_2 within a community. Finally, remote sensing of primary productivity is based on the differential absorption of light by chlorophyll and other leaf pigments. We will discuss each technique individually.

The most accurate way to measure NPP is to measure net the photosynthetic rates of photosynthetic tissues, then subtract the respiration rates of non-photosynthetic tissues, and extrapolate to the community level using the net production per gram of biomass of each species in the community. Until recently it has not been possible to assess NPP by this method on a large scale. Production per gram of biomass is not known for each species on Fort Benning, however it is known for many of the major species. Species not known can be lumped with surrogate species (ecological equivalents) that are known.

In communities of modest stature, the simplest approach for calculating net primary productivity is the harvest technique. For some annuals, biomass and net production are nearly equivalent. Therefore, the sequential harvest of all plant parts, during the course of the growing season, provides net productivity data. However, once stands contain appreciable biomass, i.e., early woody successional stands, it is more effective to calculate total community productivity using dimension analysis for trees and the harvest technique for herbs and shrubs. The drawback of dimension analysis lies in the complexity of a forest community. Mature forests are generally composed of a combination of tree species and ages, and converting measurements from an individual representative tree to biomass for the entire stand can lead to erroneous conclusions. Regression equations relating production to more easily measured dimensions of trees are needed.

An elementary engineering principle states that substantial enlargement of a system or structure requires a redesign of its proportions. For this reason, regressions that address the curvilinear character of plant dimensions are required. Exponential or logarithmic relationships that characterize harmonious growth with changing proportions are called “allometric equations.” In establishing standards for the development of allometric equations, sample trees are cut down and intensively measured, so that biomass, production, and other dimensions (dependent variables) can be related to diameter (independent variable) in logarithmic regressions (Lieth and Whittaker 1975). Dependent variables include: base and breast height diameter, sample branches, wood and bark diameters, bark, sapwood and heartwood thickness, weight of root crown, root, twig and leaf samples. Tree seedlings, shrubs, and herbs are treated as above. Allometric equations are very effective for climax to near-climax forests. For immature forests, the relation of biomass to productivity is highly variable and age-dependent making this method less reliable.

Many investigators have used gas exchange approaches for measuring productivity. The largest numbers of studies deal with photosynthesis of individual leaves in cuvettes, and measure the CO_2 content of air as it enters and leaves the cuvette. A method for measuring whole-community gas exchange involves measuring the daytime depletion and nighttime accumulation of CO_2 in different strata of the community. This method is known as the eddy-correlation technique and has been applied to a variety of forest and grassland ecosystems. The advantage of this approach is community characteristics such as leaf arrangement and canopy architecture are undisturbed (Lieth and Whittaker 1975).

The above methods for measuring NPP are labor intensive and expensive. Exclusive application of one method at the ecosystem level is impractical. A method for large scale NPP calculation is satellite measurement. LANDSAT (thematic mapper) satellites calculate the differential absorption of light by chlorophyll and other leaf pigments. LANDSAT measures discrete portions of the visible and infrared spectrum that are reflected by green plants. Studies in forests of the northwestern United States have enabled a direct correlation between NPP and leaf area, expressed as leaf-area index (LAI) m^2 x m^2. LANDSAT data are best suited to ecosystem scale analyses because the instrument measures reflectance in a 1km x 1km plot or pixel of land (Schlesinger 1997). Remote sensing of biomass is accomplished by taking advantage of the fact that woody vegetation absorbs and reflects microwave energy as a function of its height and the volume of water-filled tissue. The synthetic aperture radar (SAR) uses a microwave emitter and sensor mounted on an aircraft to measure reflected radiation. This technique has been used successfully to measure biomass in regrowth forests after clearing (Schlesinger 1997).

Many studies require only the calculation of woody productivity. Researchers use four methods, similar to those described above. The most accurate process requires harvest of samples of live material (tree bole, leaves, branches, and roots) from selected trees, drying to remove water, and summation of dry weights from each component to give a total weight per unit area, often g/m^2 (Bonham 1989). These data are then used in regression analysis with some easily measured dimension(s) of the live tree to predict biomass of the tree. The biomass is then aggregated to the stand or community. Accuracy of the process is increased when species are analyzed separately, when harvest occurs at the time of maximum standing crop (Bonham 1989), and when site conditions for a defined stand are homogenous.

Because this full process is time and effort-intensive, alternative approaches have been developed. A second approach uses a general regression equation in which measured or calculated vegetation characteristics, such as basal area, are mathematically correlated to biomass production. Average dimensions of trees in a stand are often used, although in an uneven-aged stand this adds bias. Accuracy of this approach is increased when multiple vegetation characteristics are available (Bonham 1989) and when the regression equations have been developed for the same species, size class and/or growth form, stage of succession, and site productivity (Elliot and Clinton 1993).

A third approach to estimating woody biomass is to measure over time the woody content of a tree, such as its stem or bole (Spurr and Barnes 1980), as a surrogate for productivity. Measurements shown to have positive relationships to productivity include stand height, tree height, crown volume, crown diameter, tree volume, stem diameter, and basal area (Brown et al. 1999, Bonham 1989, O'Neill and DeAngelis 1980, Morre 1986).

A fourth approach is use of airborne sensors. The advent of more and specialized remote sensing options adds the potential to determine productivity by sensor input and subsequent regression on factors such as LAI. The LAI is the amount of green material above a given area of ground (Archer 1973), or the foliage density. The LAI is related to NPP (Reiners 1988) although the relationship is not linear throughout time. The LAI, shape, and arrangement of the leaves describe how much light can be captured and assimilated as part of the stored carbon component of the system. The product of LAI and stand height is an expression of biomass (Mickler and Fox 1998). The LAI is considered a general structural variable of forests that allows a number of conditions to be described (Waring and Running 1998). For example, a decrease in LAI indicates that more light is reaching the forest floor, which allows a number of changes in items such as soil moisture, plant sprouting, and invertebrate colonization.

4 Available Data

In the past, the Fort Benning forest inventory protocol was designed primarily for silviculture purposes. Therefore, metrics reflect harvest information more than ecological sensitivity. The collected metrics were: forest type, basal area of pines and of hardwoods, basal area of long leaf pine, number of 10-inch pine stems per acre, and number of long leaf pines per acre. Data for subplots undergoing harvest include: species type, age, height, and bored trees.

With the consideration and implementation of the installation's Integrated Natural Resources Management Plan, the data collection methods were revised. Field data now fall within three levels: point, stand, and tract. Data pertinent to the calculation of primary production at the point level will be collected on 1/10 acre subplots, and include relevant metrics such as DBH and height by species, crown class, and percent cover. Stand level data are collected for acreage of stands. Pertinent data for calculating primary production include: a description of the forest type and stand structure, the predominant forest type, secondary forest type, and stand age structure.

In addition to data collected by the Fort Benning Natural Resources Branch, the following studies have been implemented to address specific ecosystem questions (Table 2):

Table 2. Ongoing Studies

What	How	When	Where	Who
DBH by species	Benning Forest Inventory Protocol	$1/10^{th}$ of forest compartments each year starting in 2002	Delta training compartments are next in line to be inventoried	Fort Benning forestry staff
Allometric equations for species	Via literature search and local University contacts	Ongoing	Fort Benning area and southeast	Jeff Fehmi of CERL
Yearly net primary production	MODIS derived product	Should be available in 2002	Fort Benning area at 1 kilometer resolution	NASA
8-day FPAR and LAI product, and 8-day net photosynthesis	MODIS derived products	Available since Dec 2000	Fort Benning area at 1 kilometer resolution	NASA
Aquatic productivity	Periphyton dry mass, periphyton ash-free dry mass, primary productivity rate	Each year in Spring	Nine streams on Benning (these may change as a result of ongoing revisions of the protocol	Drew Miller, ECMI group
Aquatic decomposition	Litter dry mass, litter ash-free dry mass, size distribution of litter	Every odd year, 2003 is next	Nine streams on Benning (may change)	Drew Miller, ECMI group
Stream gross primary production rates	Whole-stream one-station diurnal dissolved oxygen change technique	Several days each quarter	11 streams (most 1^{st} order)	Mulholland and Houser
Stream respiration rates	Whole-stream one-station diurnal oxygen change technique	Several days each quarter	11 streams (most 1^{st} order)	Mulholland and Houser
Soil carbon	0-horizon and mineral soil	Spring 2000, Spring	Multiple locations (40)	Chuck Garten & Tom

Table 2. Ongoing Studies				
What	**How**	**When**	**Where**	**Who**
estimates	samples (to 40 cm soil depth); separations of mineral soil C into labile and organomineral fractions	2001, Fall 2001, Spring 2002. Available at ECMI Website	under different land covers (2000), disturbed, clear-cut, and control forests (2001), K11 experimental area (2001, 2002)	Ashwood (ORNL Team 2)
Soil total carbon	Dry combustion method (CNS analyzer); 0-20 cm soil depth (uplands); 0-5 or 0-10 cm depth (wetlands)	Single events (2000, 2001); seasonal at selected sites (for use with biomass measurement). Available at ECMI Website	Scattered sites (2000); transects in D4, D12/13, D15 (ongoing); additional sites planned	Bill DeBusk
Soil microbial biomass C	Fumigation-extraction procedure (biomass C); 0-20 cm soil depth (uplands); 0-5 or 0-10 cm depth (wetlands)	Single events (2000, 2001); seasonal at selected sites. Available at ECMI website	Scattered sites (2000); transects in D4, D12/13, D15 (ongoing); additional sites planned	Bill DeBusk
Soil β-glucosidase (enzyme) activity	Fluorometric microtiter plate enzyme activity assays; 0-20 cm soil depth (uplands); 0-5 or 0-10 cm depth (wetlands)	Single events (2000, 2001); seasonal at selected sites. Available at ECMI website	Scattered sites (2000); transects in D4, D12/13, D15 (ongoing); additional sites planned	Bill DeBusk and Joe Prenger (UFLG)
Soil erosion/deposition estimates	Laser measured surface profiles and derived TIN surface for each plot	Each Spring, second re-sample in March 2002	10, 20x20 meter plots in each, Sally and Bonham watersheds and six additional plots co-located with LCTA plots	ECMI group
Leaf litter fall		32 1 ha sites once per quarter	Training compartments A, B, C, D, F, I, M, O, Q, T	John Dilustro
Pinus palustris litter decomposition rates		16 1 ha sites last 12 months once per quarter	Training compartments C, D, F, M, Q, T	John Dilustro
Mineral soil and 0 horizon C content		32 1 ha sites in 2001 once per year	Training compartments A, B, C, D, F, I, M, O, Q, T	John Dilustro
in situ soil carbon flux		4 sites mid-2001 once per quarter	Training compartments D, F, O	John Dilustro
Understory vegetative biomass estimates		Peak biomass sample for 2002?		John Dilustro
DBH by species		34-1 ha sites once per year	Training compartments A, B, C, D, F, I, M, O, Q, T	John Dilustro
Sapling biomass				John Dilustro
Pinus taeda litter decomposition rates	Leaf packs in litter	Spring & fall	12 sites: uplands and bottomlands at 6 sites, 3 replicates each	John Zak
Microbial carbon biomass	Soil samples	Spring & fall	12 sites: uplands and bottomlands at 6 sites, 3 replicates each	John Zak
Soil organic matter	Soil samples	Spring & Fall	12 sites: uplands and bottomlands at 6 sites, 3 replicates each	John Zak
Tree density by species	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
DBH by species	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic

Table 2. Ongoing Studies				
What	**How**	**When**	**Where**	**Who**
Woody ground cover by species	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
Litter cover	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
Grass cover	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
Forb cover	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
Legume cover	Plot samples	Spring	Currently 9 sites: high, med, low disturbance More sites in 2002	Tony Krzysik & Dave Kovacic
Soil PLFA		Fall 1999 Available at ECMI Website	Anthropogenic disturbance gradient within a long-leaf pine habitat	A.D. Peacock, S.J. Macnaughton, J.M. Cantu, V.H. Dale, and D.C. White (UT Knoxville)
Stream chemistry	Samples manually collected and filtered (Gelman Acrodisc© 0.45 μm) analysis at ORNL laboratory	Bimonthly samples. Available at ECMI Website	All streams	J.W. Feminella, K.O. Maloney, and P.J. Mulholland (Oak Ridge National Laboratory)
Stream storm chemistry data	ISCO model 6700 sampler triggered to sample at specified time interval once water level exceeded a pre-set value. Analysis at ORNL laboratory	Before, during and aForter storm events. Available at ECMI Website	1st and 3rd order streams	P.J. Mulholland (Oak Ridge National Laboratory)

In addition to the above cited data, extensive GIS coverage is available through the SEMP data repository including: Forest Inventory, Forest Compartments, Prescribed Burn Units, Ecological Units of the Eastern United States, 1928 Soil Survey for Fort Benning Exclusion Zones, and Fort Benning Soil Surface Texture. Species of particular interest at Fort Benning are loblolly pine (*Pinus taeda*), slash pine (*Pinus elliottii*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*).

5 Calculating Productivity

When addressing the question of whether or not sufficient data are being collected at Fort Benning to analyze terrestrial system productivity, the method(s) and sampling design must be considered. Criteria for evaluating adequacy of data include the spatial and temporal coverage of each method, resolution of data (scale of data as well as their accuracy and precision), redundancy among methods, and transportability to installation personnel and funding.

Of the several techniques that were briefly described, no one method addresses all ecosystem components with equal precision. Therefore, it is recommended that a suite of methods be used for calculating productivity on Fort Benning.

Considering herbaceous vegetation and woody ground cover, the harvest technique proves to be the easiest and most accurate at this time. The data collection efforts of Dilustro and Krzysik and Kovacic may address this requirement (Table 2). As herbaceous and woody ground cover gives way to sapling and young trees, an alternate technique must be adopted. The use of allometric equations in regressions best addresses the challenge of tree stands with a heterogeneous mix of age and species composition. We are in the process of determining if regional allometric equations for individual species found at Fort Benning are adequate or if site-specific equations will be necessary. Again from Table 2, the Fort Benning forestry staff, Dilustro, and Krzysik and Kovacic collect tree dimensions, such as DBH. DBH, a dependent variable, can be used in allometric equations for calculating net primary productivity by species.

While allowing a high degree of accuracy, the harvest technique and allometric equations are labor and resource intensive. The results of these research efforts could be used to calibrate MODIS values when they become available in 2002. As correlations between field values and remote sensing values become clear, extrapolation of MODIS values across Fort Benning, the hydrologic unit, or the region can be calculated.

By using this suite of methods, it is possible to calculate terrestrial ecosystem productivity at Fort Benning. Table 3 (will) summarizes required data for productivity calculations, as illustrated for allometric equations.

Table 3. Data required for productivity calculations

Information	How obtained	When	Where
Allometric equations for tree species of concern	Literature search/development	Ongoing	Fort Benning area and immediate Southeast

6 Conclusions

Many pieces of vegetation and climate data are being collected or planned for collection at Fort Benning. Whether or not sufficient data are being collected to analyze terrestrial productivity relies upon (1) clarification of data collection procedures, and (2) subsequent evaluation of data collection using criteria listed in section 5.

Regarding collection of grass, forbs, legume and woody ground cover in implementing the harvest technique, any assumptions or guidelines regarding vegetation must be agreed upon at the onset of data collection. Two considerations may be how to account for herbivory or loss of vegetation due to storm damage.

In the development of allometric equations, consideration of community makeup and unique characteristics of the component species must be accounted for. At present, we are assuming that DBH will be the dependent variable in the equations. That assumption must be verified.

Since MODIS data are not yet available, their efficacy for NPP determination remains to be seen. The correspondence of field values compared to MODIS values will require close scrutiny as soon as they become available.

Assuming field data collection strategies and allometric equations are appropriate and MODIS data corresponds positively with field results, a preliminary determination is that sufficient data are being collected to analyze terrestrial primary productivity at Fort Benning.

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