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Realizing the Value of Photosynthetic Biomass: The Role of Analog Forestry.

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Abstract:
The most critical and valuable material in maintaining the life support system of the planet is its photosynthetic biomass. Yet this material has been conspicuously under appreciated and unvalued to date. The valuation of the current carbon market in addressing climate change provides real benchmarks and suggests astounding market opportunities. The Analog Forestry system of farm based environmental restoration, emerges as a promising technology to help capitalize photosynthetic biomass.

The evaluation of the pools of planetary carbon had received great attention as rising concerns of climate change and biomass loss emerge. The global trends are clear--there is an increasing rate of loss in biodiversity and biomass, a trend that commenced about 700 years ago and that loss is accelerating. The loss of biodiversity and biomass signifies a reduction in our biological potential to survive, due to the fact that a large contribution to the biological quality of life is provided by the living component of the environment. This loss is best understood by observations on the importance of terrestrial biomass, which has often been likened to the living skin of the planet.

Bradshaw (1993) states, the physiognomy and well being of our planet depends on its living skin, without which land would become unstable. This living skin or terrestrial biomass is most valuable when it represents the maximum volume of mature biomass. It is significant that the most mature terrestrial ecosystem is not only the one that contains the largest volume of biomass, but also highest in biodiversity; usually represented by forests, these ecosystems provide the highest value. Biomass is a complex mixture of organic materials, such as carbohydrates, fats, and

proteins, along with small amounts of minerals, such as sodium, phosphorus, calcium, and iron. The main components of plant biomass are carbohydrates (approximately 75%, dry weight) and *lignin* (approximately 25%), which can vary with plant type (Anon 2000). In terms of its role in forestry, biomass is defined as the total amount of aboveground living organic matter in trees expressed as oven-dry tons per unit area (Brown 1997). Biomass is present as living and non-living components. The total live biomass on earth is about 560 billion tonnes C. Most of this biomass being found on land, with only 5 to 10 billion tonnes C found in the oceans (Groombridge et al 2000). Marine and terrestrial primary 2 producers yielded an estimated global net primary production (NPP) of 104.9 Gt of carbon per year, with 56.4 Gt tonnes C/ fixed per year through terrestrial
primary production and the rest from the ocean. (Field et al 1998). While the volume of living biomass has now been captured on most global models of carbon cycling and as the measure of living biomass is being used in the evaluation of carbon stocks with increasing frequency (Ruesch 2000), there is a an urgent need to address a fundamental difference between the components of living biomass. Living biomass is present as two fundamentally different units, photosynthetic biomass and respiring biomass. The difference between photosynthetic and respiring biomass is that photosynthetic biomass performs the act of primary production, the initial step in the manifestation of life. The biomass so termed has the ability to increase in mass through the absorption of solar or other electromagnetic radiation while releasing oxygen and water vapor into the atmosphere. Respiring biomass is that component of living biomass that uses the output of primary production to make the complicated biological patterns of life; it consumes oxygen to power its functions, and does not have photosynthetic functions itself. This distinction would seem to be fundamentally important when assessing the value of biomass that is being addressed. The consideration of biomass that contributes to terrestrial primary production as a distinct biomass pool is urgent. As discussed above, it is only photosynthetic biomass that powers carbon sequestration, carbohydrate production, oxygen generation and water transformation, i.e. all actions essential for the sustainability of the life support system of the planet. Yet strangely, it is the product of photosynthetic biomass, as sequestered carbon, usually represented by

wood/timber that has received commercial value in the carbon market for mitigating climate change. The photosynthetic biomass for terrestrial ecosystems is largely composed of the leaves of terrestrial vegetation. While the photosynthetic component of marine ecosystems are comprised mostly of marine algae and phytoplankton. In terrestrial systems, it is the leafy component that contributes to primary production. This component varies greatly in size and temporality. Further, the adaptive architectural structure of shrubs was seen to vary greatly from trees (Prickett and Kempf 1980, Nicola and Prickett 1983).

In a forest, shade-tolerant, late-succession tree species possess significantly larger leaves compared to early-succession, shade-intolerant species (White, 1983). Usually, leaf sizes and leaf numbers tend to be negatively correlated, i.e. the larger the leaf-size the less in number and viceversa. This relationship has been measured for some trees. Large leaved trees such as *Catalpa sp* having about 26,000 leaves while younger, small leaved *Citrus sp* had over 90,000 leaves (Kozlowski 1971). Although the numbers vary greatly, the mean mass of leaves produced does not seem to vary much between different plant groups. The measured mean of annual leaf production in temperate forests has been reported as 2.8 metric tons/ha/yr for angiosperms and 2.7 metric tons/ha/yr for gymnosperms (Senanayake and Jack 1998). Trees have an approximate ratio of 10:1 between non-photosynthetic and photosynthetic biomass. Currently the total amount of terrestrial carbon is estimated at approximately 359 billion tons (Plantinga et al 2008). Of this, forest vegetation stores 283 Gt in its biomass (Markland and Shoene 2005). As the weight of tree leaves account for approximately 10% of this total biomass, a figure of 28.3 billion tons of photosynthetic biomass is indicated. It is the forests and the savannas that comprise the aboveground, photosynthetic biomass. The non-tree (savanna, woodland) photosynthetic biomass is more temporal than trees but possess a higher leaf to stem and root ratio. The non-tree biomass accounts for 76 Gt which at 80% photosynthetic biomass provides about 60.8 billion tons and marine photosynthetic biomass contributes about 3-4 million tons to the global standing stock .

In terms of primary production, photosynthetic biomass accounts for a rate of about 426 gC/m2/yr for land and 140 gC/m2/yr for the oceans. Although the total weight of terrestrial biomass is about twenty times that of marine photosynthetic biomass and sequestration rate per unit area four times that of the ocean, the two pools contribute about equally to global primary production. This is due to the high turnover rates in the marine ecosystems. This feature should be kept in mind when considering the relative value of the different types of photosynthetic biomass.

The sheer power of operation of terrestrial system is seen when the volume of water released from photosynthetic biomass is considered, at a water release rate of 100:1, where over 100 molecules of water are released for each molecule of carbon dioxide absorbed by the leaf (Jones 1976). The quantity of water released annually by forests and grasslands are like aerial rivers cycling about 2830 billion tons of water into the atmosphere at ever turn of leaf weight. This quantity of evaporative water not only influences local cooling events greatly, but also contributes to the distribution of heat in the atmosphere. This action also creates one on the most significant consequences of evapotranspiration by terrestrial vegetation, which is the 'cleaning' effect on water, releasing ground water that has been freed of the chemical pollutants that it was once burdened with. This cleaning function is hardly recognized nor evaluated.

Leaves are the ideal organs to carry out these functions effectively, as leaves present an extensive surface area to the environment. For example, 0.5 ha of Oak forest with a basal stem area of 5.5 sq m produced an aggregate leaf surface area of more than 2.03 ha (Rothacher et. al. 1954). The leaf surfaces also provide another critical element in water cycling. The streams and rivers of water vapor that flow in the atmosphere as water vapor are generally invisible. It is made visible by the existence of minute particulate matter that condenses the water vapor into viable forms, termed clouds. This particulate matter, termed Cloud Condensation Nuclei. (CCN) is comprised of bacteria and bacterial particles (Ahern et al 2006) and biotic chemicals like Di Methyl Sulphide (DMS) and plant aerosols (Charlson et al 1987). The largest sources of CCN from terrestrial sources are the leaf surfaces and pores of plants which harbor and release large quantities of bacteria and bacterial particles. In mature forests this function is increased greatly by the epiphytic communities which also create CNN from both leaf surfaces and community interstices. This contribution is significant and further underscores the value of conserving old growth forests. For example, in the old growth forests of the Colombian Andes the epiphyte biomass was estimated at about 12 tonnes dry weight per hectare (Veneklaas et al 1990). The oxygen generation function is taken for granted, but as the recent studies on the hole in the stratospheric shield of ozone show, the act of controlling ozone depleting substances, will not produce results for many years due to the lag-time effect. Even though several chemicals harmful to ozone including the chlorofluorocarbons (CFCs) that were once in widespread use as refrigerants have been phased out under the Montreal Protocol of 1987, they last longer in atmosphere thereby causing damage. This is expected to last for several decades' (WMO 2011). Increasing the oxygen producing function of the biosphere, can certainly contribute to the stabilization of the ozone shield. It can also help to allay the impact of massive rates of combustion required for much of modern society. However up to date we have failed to recognize the economic value of the oxygen generation function. Thus it seems imperative that a real value be placed on photosynthetic biomass; initial computations can begin by considering the current values suggested for the global market for similar functions. The estimated value of the carbon market, was in excess of 125 billion in 2008 as reported in Environment Leader (2010), with an estimated growth up to 500 Billion dollars by 2012. As it is a matter of public discourse, these figures provided by both government and intergovernment organizations are useful indicators. Thus if we consider the current value of 125 billion dollars to contain climate change, the value of photosynthetic biomass can now be addressed. Assuming that the market would bear at least the value of controlling climate change, on the ability to breathe, the 93.1 billion tons of photosynthetic carbon currently in stock would be roughly worth about 1.35 dollars per kilogram. This comes as a surprise when the current models of carbon sequestering to combat climate change is examined, many models discount or place a low value of leaves and twigs which are often removed before the sequestered carbon is measured (FAO 2001, FAO 2002). This photosynthetic biomass, often considered to be too temporal in accounting for carbon sequestering, is actually the most valuable component. While the total photosynthetic biomass suggests a base value, this value is modified using variables such as net primary production (NPP) as a multiplier to reflect production efficiency. Thus, photosynthetic biomass, often considered to be too temporal in accounting for carbon sequestering, is actually its most valuable component. Slowing down the loss of global terrestrial photosynthetic biomass stock is not an option - it is a critical need! A massive investment must go towards incrementing the global photosynthetic biomass stock. The potential value of this stock can also attract the investment to develop market growth. Thus a discussion of the models of high utility and high photosynthetic productivity is urgent. The recognition and evaluation of photosynthetic biomass must become a primary driver of the restoration processes discussed above. It can energize the restoration of biodiversity and the restoration of environmental services. The current approaches to tree farming and forest management needs to accept this potential of photosynthetic biomass and work towards realizing its value. For management purposes, the photosynthetic biomass of a natural ecosystem has to be seen as a continuum of native species from the early seral stages represented by annuals and short-lived species, to shrubs and bushes, to pioneer trees, to the mature tree dominated, old growth forest. If each stage is encouraged to carry its full complement of photosynthetic biomass, it will ensure that the management plans address the generation and maintenance of the optimal levels of photosynthetic biomass in each seral stage and gain the corresponding value. This process is the obverse of current land use trends that incrementally destroy the photosynthetic biomass potential through clearing and the establishment of even aged monocultures. This perspective of a forest as a process, as well as the fact that, in terms of the biodiversity of any natural forest, trees account for only about 1% of a forests biodiversity or less, suggests that the inclusion of a non-crop biodiversity and a greater quantity of vegetation within the structure of established plantations could become a lucrative venture for plantation and woodlot owners. The most effective, tested approach to creating such vegetational complexes within degraded and anthropogenic areas is *Analog Forestry* (Senanayake and Jack 1998). This approach, seeks to develop a tree dominated ecosystem analogous to the original climax community, but recognizes the other non-tree photosynthetic growth forms in any given ecosystem and includes them in the

management area by design. The recognition and evaluation of photosynthetic biomass must become a primary driver of such restoration processes. Restoration of biodiversity and environmental services must be the other. Analog Forestry is a silvicultural technique that seeks to establish a tree dominated ecosystem analogous in architectural structure and ecological function to the original climax or sub-climax vegetation community. In addition to the restoration of biodiversity, it also restores environmental services. It seeks to empower rural communities both socially and economically, through the use of native and exotic species that provide marketable products and develop forest structure. The process was initiated and developed in Sri Lanka in 1980, as a response to the *Pinus* and *Eucalyptus* monocultures that were being planted in Sri Lanka to compensate for the loss of natural forests. Even though the total forest biomass is more stable in the mixed plantations than monoculture.(Li et al 2010).
Analog Forestry (AF) in addition to providing agricultural diversity, follows ecological observations in generating design. For example, in Brazil four species of frogs breed only in Peccary wallows or other small permanent ponds. Conserving these frogs depended on maintaining peccaries or mimicking their wallows (Soule and Khom 1989). When such ecosystems are designed onto the landscape, the dependent animals or plants can sustain populations. When such design approaches are utilized, the target organisms often become effective biodiversity indicators or bio-indicators of the health of that eco system (Senanayake 2004).
Analog Forestry has also moved the dialogue on poly-culture planting to a new arena, that of biodiversity development and ecosystem restoration. The experimental plots AF in Sri Lanka have recorded an exponential increase in birds, amphibians, reptiles and soil invertebrates It has also facilitated the return and re-establishment of populations of the endemic Jungle Fowl and Lady Torrington's Wood Pigeon both of which were locally extinct in the region prior to the application of AF plantings. (NSRC 2002).
It follows that such a system of land management will best be monitored by its bio-indicators. This consideration is included in a system of certification based on biodiversity indicators that has been developed over the last 20 years and is termed Forest Garden Product (FGP) certification (www.forestgardenproductcertification.com). The system operates on the assumption that biodiversity provides the most accurate

indicators of a sustainable ecosystem and that with the use of biodiversity indicators, the credibility of organic or biodiversity friendly production systems will be increased. It is now incumbent on a global or international institution to bring the issue of restoration to the fore. If economic and policy decisions create a climate conducive to placing a value on restoration and on photosynthetic biomass, these critical activities can be developed and the current trends can be addressed. The greatest resource to respond to these goals of restoration and photosynthetic biomass increase are the rural poor. It is only the day-to-day attention to new plantings in the field and an increasing knowledge on the theory and practice of restoration that will produce the healed environments of tomorrow.

Consideration of the rural populace as key players in land management is important because it is the rural person who will often be responsible for the acts that destroy or develop biodiversity and photosynthetic biomass. It is the inability to place value on these real goods that keeps beggaring the farming communities, negatively affecting their attendant biodiversity and the life support systems of the planet.

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