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Review

More than just trees: Assessing reforestation success in tropical developing countries

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A B S T R A C T

Rural communities in many parts of the tropics are dependent of forests for their livelihoods and for environmental services. Forest resources in the tropics have declined rapidly over the past century and therefore many developing countries in the tropics have reforestation programs. Although reforestation is a long-term process with long-term benefits, existing evaluations of the success of these programs tends to focus on short-term establishment success indicators. This paper presents a review of reforestation assessment that highlights the need to not only consider short-term establishment success, but also longer-term growth and maturation success, environmental success and socio-economic success. In addition, we argue that reforestation assessment should not be based on success indicators alone, but should incorporate the drivers of success, which encompasses an array of biophysical, socio-economic, institutional and project characteristics. This is needed in order to understand the reasons why reforestation projects succeed or fail and therefore to design more successful projects in future. The paper presents a conceptual model for reforestation success assessment that links key groups of success indicators and drivers. This conceptual model provides the basis for a more comprehensive evaluation of reforestation success and the basis for the development of predictive systems-based assessment models. These models will be needed to better guide reforestation project planning and policy design and therefore assist rural communities in tropical developing countries to alleviate poverty and achieve a better quality of life.

1. Introduction

The United Nations Food and Agriculture Organisation (FAO) estimates that more than 1.6 billion people worldwide depend on forests for their livelihood, including 60 million indigenous people who are almost wholly dependent on forests and with 350 million people living within or adjacent to dense forests depended on them for subsistence and income (FAO, 2001). In developing countries specifically, The World Bank have estimated that forest resources directly contribute to the livelihoods of 90 percent of the 1.2 billion people living in extreme poverty and indirectly support agriculture and food supplies of nearly half the population of the developing world (World Bank, 2004). Figures of similar magnitude have also been reported by the FAO (2001) with estimates of 1.2 billion people in developing countries reliant on agroforestry farming systems for food and to generate income.

In rural areas of the humid tropics, it is estimated that 500 million people depend on a mixture of agricultural and forest resources to maintain their livelihoods (Maginnis and Jackson, 2002). Therefore, rural communities in tropical developing countries rely heavily on the extraction of timber and non-timber resources from forests, and often on the conversion of forests to agriculture and other uses as well. Forest ecosystem services such as water purification and crop pollination (by providing a habitat for pollinating insects, birds and mammals) likewise play a key role in supporting rural livelihoods (IUCN, 2007).

The loss of tropical forest resources on which millions of rural people depend has been rapid over the past century. An estimated 350 million hectares of tropical forests have been deforested and a further 500 million hectares of secondary and primary topical forests have been degraded (ITTO, 2002). Despite the traditional heavy dependence of rural communities on tropical forests, tree cover no longer dominates many tropical forest landscapes. In some areas, the current land-use configuration has led to a dramatic and detrimental decline in the availability of forest goods and services (Maginnis and Jackson, 2002). In such degraded landscapes, agricultural production tends to suffer, local shortages of timber and fuelwood occur, household income falls, and biological diversity declines. Often, the effects of landscape degradation are felt

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downstream due to an increase in silt loads and a decline in water quality (Maginnis and Jackson, 2002).

Reforestation can help reverse some of the more severe impacts of forest loss and degradation on rural communities in the tropics by providing secure access for local people to a range of forest products, including fuelwood and non-timber forest products; improved hydrological regulation and nutrient cycling; providing more diverse and better connected habitats, thus supporting more biological diversity; and options to increase the resilience and adaptability of existing agricultural systems (Maginnis and Jackson, 2002).

On a global scale, reforestation in the tropics is considered an important means of climate change mitigation (Canadell and Raupach, 2008). Palm et al. (2005) estimate that 300 million to 1 billion hectares of land is available for reforestation in the humid tropics and that given the area of land available, reforestation in the humid tropics alone would sequester 27 to 90 billion tonnes of carbon. Afforestation and reforestation are common forestry activities included in trading schemes for carbon sequestration offsets. Successful reforestation projects must result in established stands to qualify as an offset. Forest biomes store as much as 10 times more carbon in their vegetation than do non-forest biomes, usually at least for decades, and for centuries in some ecosystems (Saundry, 2009).

To preserve the livelihoods of rural communities in the tropics, and for global climate change mitigation, it is clear that reforestation is necessary. Governments and international aid agencies commit substantial resources in tropical countries to restore forests (Iyyer, 2009). Despite substantial expenditure on reforestation, little information exists to indicate the success of reforestation projects in achieving ecological or socio-economic benefits. Unfortunately, many existing reforestation projects have partially or completely failed because the trees planted have not survived or have been rapidly destroyed by the same pressures that have caused forest loss and degradation in the first place. Dudley et al. (2005:4) stated that, "Anyone working regularly in the tropics becomes accustomed to finding abandoned tree nurseries, often with their donor organisations' signboards still in place, the paint gradually peeling away". Even when planted trees have survived to maturity, they have not necessarily been welcomed by local communities. One example is the widespread controversy over reforestation with exotic monocultures of eucalyptus in the tropics (Carrere and Lohmann, 1996).

Ensuring long-term success is one of the greatest challenges facing many reforestation initiatives in developing countries. However, most evaluations of reforestation success have been narrowly focused on reaching planting area targets. Few evaluations have measured the environmental or socio-economic success of reforestation projects. In addition, little is known about what influences the success of reforestation projects and in what situations reforestation projects succeed or fail. More holistic, integrated approaches to assessing reforestation success are needed.

In this paper, we develop a conceptual framework for evaluating and planning reforestation projects in tropical developing countries that incorporates both the biophysical and socio-economic indicators of success, and also the drivers of success. This paper focuses on assessing projects funded externally by government and non-government organisations (NGOs). There are also many trees planted by ordinary people for their own reasons (i.e. based on their personal 'conceptual frameworks') but these private initiatives are beyond the scope of this review. In this paper, the success indicators (performance measures) that have been applied in the tropics and internationally are reviewed first, and then related to the key biophysical, environmental and socio-economic drivers that affect success. Next a conceptual model that integrates the indicators and drivers of reforestation success as the basis for reforestation planning and success assessment is presented.

2. What is meant by reforestation success?

Reforestation is the process by which trees are returned to areas from which they have been previously cleared. Reforestation can take many forms, ranging from establishing timber plantations of fast-growing exotic species through to attempting to recreate the original forest type and structure using native species. In whatever form it takes, reforestation is a long-term endeavour. For example, it has been estimated that full recovery of the composition and structure typical of 'an intact' rainforest (starting from cleared land or highly degraded forest) would take at least 50 years in the tropics and 100 years or more in the extra-tropical zones (Hopkins, 1990; Mansourian et al., 2005a). Reforestation projects typically progress through two main stages: an initial 'establishment' phase and a long-term 'building' phase (Kanowski and Catterall, 2007). Reforestation success can therefore be viewed as a continuum from the successful establishment of the initial planting through to maturation and realisation of the full environmental and socio-economic benefits of the forest (Reay and Norton, 1999). This means that the measures of success will differ at different stages in a reforestation project. Undertaking assessments at an early stage of a reforestation project can only indicate likely future success (Reay and Norton, 1999). As the forest matures more information is required to make judgements about environmental and socio-economic success (King and Keeland, 1999; Reay and Norton, 1999).

Knowing the objectives of reforestation is important for assessing success (Aronson et al., 1993; Brown and Lugo, 1994; Hobbs and Harris, 2001). To evaluate previous reforestation actions, both initial and current reforestation objectives need to be considered because objectives defined when the project was conceived may not necessarily match current environmental and social demands. Reforestation objectives are fundamentally valued-based (Davis and Slobodkin, 2004) and have traditionally been focused on wood production, erosion prevention and water flow management. In recent decades, the objectives have shifted towards socio-economic benefits, ecosystems goods and services, recreation and wildlife conservation (Vallauri et al., 2002).

According to the CIFOR Rehab Team (2003), the objectives of reforestation projects are to enhance productivity, livelihood, and environmental service benefits. In general, the objectives of reforestation projects are divided into physical and non-physical. Physical objectives are usually aimed at increasing forest and land cover, increasing timber production, protecting watersheds and conserving biodiversity; while the non-physical objectives are usually to increase community incomes, create livelihood opportunities, empower local communities, secure community access to land and to raise environmental awareness and education (Chokkalingam et al., 2006a; Nawir et al., 2007).

Given that reforestation is a process that has multiple objectives, a comprehensive assessment of reforestation success should cover the main stages of reforestation (from establishment to forest maturation) and the main physical and non-physical objectives.

3. Potential indicators of reforestation success

A large number of qualitative and quantitative indicators have been either reported or proposed in the literature for the assessment of reforestation success. The more common indicators are now reviewed.

Table 1
Establishment success indicators.

Establishment indicators	References
Survival rate of trees (%)	Lamb and Tomlinson (1994); King and Keeland (1999); Camargo et al. (2002); Lamb and Gilmour (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008).
Area planted compared to target area (%)	Chokkalingam et al. (2006a); Nawir et al. (2007).

3.1. Indicators for measuring establishment success

Establishment is generally referred to as a three to five year period from when seed or seedlings are planted to when young trees have 'captured' the site, forming a relatively closed canopy and suppressing weeds (Kanowski and Catterall, 2007). During the establishment phase of reforestation, the survival and growth of planted trees, and the degree of canopy closure are of particular importance. The most common indicators used for measuring establishment success are the survival rate of planted trees and the area planted compared to a target area (Table 1). These indicators are commonly measured within months of planting but might also be monitored intensively during the first three years of reforestation to account for the ability of young trees to persist in the face of weed competition.

3.2. Indicators for measuring forest growth success

Once established, trees grow, reproduce, and are harvested or eventually die. Kanowski and Catterall (2007) refer to this as the building phase of revegetation. During this phase, the focus of success is on tree growth, stand density, stem form (in the case of timber trees) and the production of non-timber forest products (such as fruit and resins). The importance of each of these success measures will depend on local circumstances and objectives. Indicators commonly reported as measures of successful growth of trees are summarised in Table 2.

3.3. Indicators for measuring environmental success

Restoring environmental values, ecosystem functions and ecosystem services is an important long-term objective of reforestation (Sala et al., 2000). In assessing the environmental performance of forests, previous studies have focused on three major ecosystem attributes: vegetation structure (Salinas and Guirado, 2002; Jones et al., 2004; Kanowski et al., 2008), species diversity (Peterson et al., 1998; Kanowski et al., 2008, 2009) and ecosystem functions (McKee and Faulkner, 2000; Davidson et al., 2004).

Measures of vegetation structure provide information on wildlife habitat suitability, ecosystem productivity, erosion resistance and the successional pathway of the forests (Jones et al., 2004; Silver et al., 2004; Wang et al., 2004). Vegetation structure is usually determined by measuring vegetation cover (of trees, shrubs and ground cover) and woody plant density (Salinas and Guirado, 2002; Kruse and Groninger, 2003; Wilkins et al., 2003; Kanowski et al., 2008) (Table 3). These indicators are usually compared to reference sites to assess the relative structural quality of the forest (Whisenant, 1999; Kentula, 2000; McCoy and Mushinsky, 2002).

Measures of species diversity provide information on wildlife habitat suitability and ecosystem resilience (Nichols and Nichols, 2003). Diversity is usually measured by determining the abundance and richness of species within trophic levels (plants, herbivores, carnivores) or functional groups (trees, shrubs, saplings, herbs) within the forest (McLachlan and Bazely, 2003; Nichols and Nichols, 2003; Weiermans and Van Aarde, 2003; Benayas et al., 2009; Kanowski et al., 2009) (Table 4).

The main ecosystem functions of forests include protection of soil from erosion, carbon sequestration, nutrient cycling and water conservation (Herrick, 2000; Herrick et al., 2006). Many authors report that the control of hydrology and nutrient cycling (Whisenant, 1999; Tongway, 2004), the capture of energy, the return of key fauna to the ecosystem (Reive et al., 1992; Block et al., 2001), and the restoration of links – flows of matter, energy and information – to the surrounding landscape (Bell et al., 1997; Huxel

Table 2
Indicators of forest growth success.

Indicators of forest growth success	References
Tree growth performance (measured by tree basal area, height, stem form)	Lamb and Tomlinson (1994); Harvey and Brais (2002); Lamb and Gilmour (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)
Stand density (for age)	Lamb and Tomlinson (1994); Harvey and Brais (2002); Salinas and Guirado (2002); Kruse and Groninger (2003); Wilkins et al. (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)
Area remaining intact or area maintained long-term	Chokkalingam et al. (2006a); Nawir et al. (2007)
Actual production of timber, fuelwood, resin, fruit (amount/ha)	Lamb and Gilmour (2003); Chokkalingam et al. (2006a); Nawir et al. (2007)

Table 3
Vegetation structure indicators.

Vegetation structure indicators	References
Canopy cover	Salinas and Guirado (2002); Kruse and Groninger (2003); Lamb and Gilmour (2003); Wilkins et al. (2003); Chokkalingam et al. (2006a); Gillison (2006); Nawir et al. (2007); Kanowski et al. (2008); Kanowski et al. (2009)
Canopy height	Gillison (2006); Kanowski et al. (2008); Kanowski et al. (2009)
Ground cover	Salinas and Guirado (2002); Kruse and Groninger (2003); Lamb and Gilmour (2003); Wilkins et al. (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008); Kanowski et al. (2009)
Litter cover	Lamb and Tomlinson (1994); Tongway (2004); Kanowski et al. (2008); Kanowski et al. (2009)
Shrub cover	Salinas and Guirado (2002); Kruse and Groninger (2003); Wilkins et al. (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008); Kanowski et al. (2009)

Table 4
Indicators of species diversity.

Species diversity indicators	References
Tree species richness	Aronson et al. (1993); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008); Kanowski et al. (2009)
Presence of desired tree species	Lamb and Tomlinson (1994); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)
Appropriate wildlife species present	Lamb and Gilmour (2003); Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)
Special life forms	Aronson et al. (1993); Kanowski et al. (2008); Kanowski et al. (2009)
Weed abundance	Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)

and Hastings, 1999) are all essential to ecosystems. Surface soil stability, the absence of erosion, soil organic matter and soil fertility levels are common measures used to assess the soil protection function of forests. Water quality and quantity are commonly used to assess water conservation while biomass and soil carbon are commonly used to measure carbon sequestration (Table 5).

3.4. Indicators for measuring socio-economic success

For reforestation to be attractive to local communities, it needs to provide socio-economic benefits. As a pre-requisite for achieving long-term reforestation success, local people must receive benefits exceeding those from alternative land uses, otherwise reforested areas will continue to be cleared (Ramakrishnan et al., 1994). The socio-economic benefits of reforestation do not necessarily have to be direct and can include 'avoided negative impacts' (e.g. landslide prevention or preservation of timber reserves). The most common indicators used for measuring socio-economic success of reforestation are local income, local employment opportunities, other livelihood opportunities, provision of food and fibre, stability of market prices of locally produced commodities, and local empowerment and capacity building (Table 6).

4. Potential drivers of reforestation success

While indicators are required to measure success, they alone do not account for the circumstances that influence or contribute to success (Hayword and Sparkes, 1990). In order to influence or predict the success of reforestation projects, an understanding of a range of success drivers is required. Many authors state the importance of socio-economic drivers, often regarding them as more important than biophysical ones (Lamb, 1988; Walters, 1997; Crk et al., 2009). In a study of six tropical countries, Chokkalingam et al. (2005) identified three requirements for sustaining reforestation efforts: 1) strengthen local organisations and participation in projects, 2) consider socio-economic needs in choices and options, and 3) ensure clear and appropriate institutional support and arrangements. Chokkalingam et al. (2005) also identified local knowledge of tree characteristics, planting of diverse species of ecological and economic importance, and integration of reforestation programs with regional development strategies as essential elements of reforestation success. Using data from the same study as Chokkalingam et al. (2005), de Jong et al. (2006) identified 27 factors influencing reforestation outcomes and grouped these into six categories: 1) policies and legislation, 2) players, actors and arrangements, 3) funding, 4) objectives of the reforestation, 5) technology, and 6) extension, technical assistance and training.

From previous studies it is clear that there is a wide range of factors that influence reforestation success and that success cannot be explained by a single factor. Rather, success results from a number of biophysical, technical and socio-economic drivers acting together (Sayer et al., 2004). In this section, we review the commonly reported success drivers and divide them into four main categories: 1) technical and biophysical factors; 2) socio-economic factors; 3) institutional, policy, and management factors; and 4) characteristics of the reforestation project.

4.1. Technical and biophysical drivers

The technical and biophysical constraints to reforestation success most commonly mentioned by authors include site-species matching, site preparation, tree species selection, seedling production, quality of seeds and seedlings, time of planting, technical capability of implementers, post-establishment silviculture, and site quality (Table 7).

4.1.1. Site-species matching

Site-species matching is vital for good survival and growth of planted trees. Site-species matching is a pre-requisite for promoting good stand growth and maintaining long-term sustainability (Chokkalingam et al., 2006b). Poor site-species matching is the main technical problem leading to poor short-term survival and growth of seedlings (Gilmour et al., 2000; de Jong et al., 2006; Chokkalingam et al., 2006a, 2006b; Nawir et al., 2007). However, site-species matching is often ignored in reforestation projects, with available rather than suitable species being planted (CIFOR Rehab Team, 2004).

4.1.2. Species selection

The species of tree selected for reforestation can have a large influence on both the benefits derived from tree products and the ecological benefits of the forest (Montagnini, 2005). Selection of appropriate species to meet livelihood needs and generate additional income for investment in reforestation is the key to the long-term sustainability of reforestation initiatives, because for farmers, reforestation means moving away from their current land-use practices (CIFOR Rehab Team, 2004). Therefore, the success of any reforestation effort strongly depends on species that can fulfil the demands of local people and cope with the site conditions and predominant competing vegetation (Günter et al., 2009). Lamb

Table 5
Indicators for measuring ecosystem functions.

Ecosystem function indicators	References
Stable soil surfaces	Lamb and Gilmour (2003); Tongway (2004); Pellant et al. (2005); Herrick et al. (2006)
Soil erosion	Tongway (2004); Pellant et al. (2005); Chokkalingam et al. (2006a); Herrick et al. (2006); Nawir et al. (2007)
Soil fertility	Tongway (2004); Chokkalingam et al. (2006a); Nawir et al. (2007)
Landslide frequency	Chokkalingam et al. (2006a); Herrick et al. (2006); Nawir et al. (2007)
Adequate quantity of surface and ground water	Lamb and Tomlinson (1994); Chokkalingam et al. (2006a); Nawir et al. (2007)
Water quality	Chokkalingam et al. (2006a); Nawir et al. (2007)
Soil organic matter	Aronson et al. (1993)
Biomass productivity	Aronson et al. (1993); Kanowski et al. (2008)
Carbon stock or carbon sequestration	Chokkalingam et al. (2006a); Nawir et al. (2007); Kanowski et al. (2008)

Table 6
Indicators of the socio-economic success of reforestation.

Socio-economic indicators	References
Increased local income	WWF (2003); ITTO and IUCN (2005); Chokkalingam et al. (2006a); Madlener et al. (2006); Nawir et al. (2007)
Local employment opportunities	WWF (2003); ITTO and IUCN (2005); Chokkalingam et al. (2006a); Madlener et al. (2006); Nawir et al. (2007)
Other livelihood opportunities	WWF (2003); Chokkalingam et al. (2006a); Madlener et al. (2006); Nawir et al. (2007)
Availability of food and fibre supplies	Lamb and Tomlinson (1994); Lamb and Gilmour (2003); WWF (2003); ITTO and IUCN (2005)
Stability of market prices of locally produced commodities	Lamb and Tomlinson (1994); Lamb and Gilmour (2003)
Local empowerment and capacity building	Chokkalingam et al. (2006a); Madlener et al. (2006); Nawir et al. (2007)

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Table 7
Biophysical and technical drivers.

Drivers	Comments	Examples from literature
Site-species matching	Poor site-species matching could lead to a high mortality rate and poor performance of seedlings.	Gilmour et al. (2000); Chokkalingam et al. (2006a); Chokkalingam et al. (2006b); de Jong et al.(2006); Nawir et al. (2007)
Tree species selection	Selection of appropriate species to meet livelihood needs, provide environmental benefits is the key to the long-term sustainability of reforestation.	Gilmour et al. (2000); Nair (2001); CIFOR Rehab Team (2004); Lamb et al. (2005); Chokkalingam et al. (2006a); Sidle et al. (2006); Günter et al. (2009)
Site preparation	Past failure of plantations has shown that land preparation is an important factor in the survival rate of planted trees and tree growth performance.	Stringer (2001); Dagar et al. (2001); Zhang et al. (2002)
Quality of seeds and seedlings	Physiological quality of seeds and seedlings affects the success of establishment and subsequent growth rate of trees.	Ochsner et al. (2001); Chokkalingam et al. (2006a); Chokkalingam et al. (2006b); de Jong et al. (2006); Nawir et al. (2007)
Time of planting	Planting seedlings at the right time is crucial, since this directly affects the survival of the seedlings in the field.	Nawir et al. (2007)
Technical capability of implementers	Despite facing many technical problems, government agencies felt technically competent while the other actors felt they had inadequate technical capability and needed support.	CIFOR Rehab Team (2004); Chokkalingam et al. (2006a); Chokkalingam et al. (2006b)
Post-establishment silviculture	The maintenance of newly planted seedlings in the field is a crucial project component that affects the survival of the seedlings and the sustainability of reforestation initiatives.	Gilmour et al. (2000); Fox (2002); Chokkalingam et al. (2006a)
Site quality	Site quality is the sum of the climatic, geologic, and edaphic factors that influence tree growth at a specific location.	Fox (2002)

et al. (2005) advocate establishing mixed species and native species plantations rather than traditional large-scale monocultures to provide both goods and ecological services. Mixed plantations could contribute to diversity, while also providing production gains and reducing pest damage (Chokkalingam et al., 2006a). Multi-species plantations, especially those that incorporate species that attract birds (which act as seed dispersers), can result in the improvement of floristic and wildlife diversity. First developed in Queensland, Australia, the framework species method of reforestation (Goosem and Tucker, 1995; Lamb et al., 1997; Tucker and Murphy, 1997; Tucker, 2000), involves planting mixtures of 20–30 indigenous forest tree species that rapidly re-establish forest structure and ecosystem functioning. Wild animals, attracted by the planted trees, disperse the seeds of additional tree species into planted areas, whilst the cooler, more humid and weed-free conditions created by the planted trees favour seed germination and seedling establishment.

4.1.3. *Site preparation*

Species vary in their requirements for sunlight, soil moisture and nutrients to establish and grow successfully, regardless of whether they are commercially valuable species or valued for wildlife, recreation and visual beauty. Site preparation involves the suppression and removal of weeds, and sometimes cultivation and fertilisation, to aid in the successful establishment and growth of tree seedlings (Stringer, 2001). Site preparation can also involve the construction of fences to exclude grazing livestock. Poor site preparation has been an important contributor to low survival rates of planted trees and poor tree growth performance (Dagar et al., 2001; Stringer, 2001; Zhang et al., 2002).

4.1.4. *Seedling production*

The availability of a nursery to produce seedlings, as well as having a good seedling preparation process, is important. The growing of seedlings in a nursery is the main way of raising planting stock in the tropics (Evans and Turnbull, 2004). Tree nurseries can provide optimum care and attention to seedlings during their juvenile stage, resulting in the production of healthy, vigorous seedlings (Roshetko et al., 2010). However, these basic supporting facilities are often lacking in the reforestation projects in developing countries. For example, Nawir et al. (2007) found that only 23% of reforestation projects in Indonesia had project nurseries and only 13% met the minimum standard for seedling production.

4.1.5. *Quality of seeds and seedlings*

In general, a high quality seedling is free of disease, has a straight sturdy stem, a fibrous root system that is free from deformities, a balanced root and shoot ratio, is hardened to withstand any adverse conditions of the planting site, with good carbohydrate reserve and nutrient content, and should be inoculated with symbiotic micro-organisms when necessary (Keys et al., 1996; Wightmann, 1999; Stape et al., 2001). Seedling quality is a combined function of seedling genetic quality and seedling physical condition as it leaves the nursery (Ritchie, 1984; Wightmann, 1999; Jones, 2004).

There are several reasons why it is important to use high quality seeds and seedlings in reforestation. First, the physiological quality of seeds and seedlings affects the success of establishment and subsequent growth rates of trees (Ochsner et al., 2001). Second, for production focused reforestation projects, genetic quality affects the growth of trees and the quality of marketable products, and therefore has great economic consequence (Foster et al., 1995).

4.1.6. *Time of planting*

Planting seedlings at the right time is crucial, because this directly affects the survival of the seedlings in the field (Nawir et al., 2007). Typically the most appropriate time to plant tree seedlings is at the beginning or in the middle of the rainy season. However, many factors, such as the late arrival of seedlings, or delayed release of the project budget, can mean that seedlings are planted at an inappropriate time of year (e.g. at the end of rainy season or during the dry season).

4.1.7. *Technical capability of implementers*

The technical capability of reforestation project implementers affects both the short and long-term survival of planted areas, and also tree growth and the quality of tree products. For example Chokkalingam et al. (2006a) found that many Philippine non-government agencies felt that they had inadequate technical capability to manage reforestation projects. Therefore, effective and timely technical assistance and training is required to lift reforestation success, particularly when projects are managed by non-government agencies (CIFOR Rehab Team, 2004).

4.1.8. *Post-establishment silviculture*

Silvicultural treatments applied at the establishment and early growth phase of forests are particularly important to reforestation success. For example, if not managed properly, weeds can cause reforestation failure through competition and through increased fire hazard and shelter for pest animals. Livestock grazing is also a common cause of reforestation failure in the tropics (Zhang et al., 2002) as grazing animals can kill and damage seedlings and young trees. Thinning, pruning and fertilising may also be important silvicultural treatments, especially where the production of good quality timber trees is a reforestation objective.

4.1.9. *Site quality*

Site quality is the sum of the climatic, geologic and edaphic factors that influence tree growth at a specific location (Fox, 2002). These factors determine the availability of water and nutrients. Site index (SI), which is the height of dominant and codominant trees at a specific age, is the most common measure of site quality. Site quality also affects the species of trees that can be used for reforestation. Good quality sites tend to support the establishment of high-value timber species.

4.2. *Socio-economic drivers*

Social and economic factors are regularly reported in the literature as drivers of reforestation success, and some authors (e.g. Walters, 1997) consider them to be more important than ecological factors in determining the success of reforestation efforts. Dudley et al. (2005:6) observed that, “too many restoration projects do not bother to find out what local people really want”. This is a particular problem in rural areas of developing countries because if reforestation projects do not meet community livelihood needs, then the planted trees will most likely be removed and the land either returned to agricultural production or left in a degraded state. Projects have often sought to encourage and sometimes impose tree planting without understanding why the trees disappeared in the first place and without attempting to address the immediate or underlying causes of forest loss (Eckholm, 1979). There has also often been a mismatch between social and ecological goals of conservation; either reforestation has aimed to fulfil social or economic needs without reference to its wider ecological impact, or it has had a narrow conservation aim without taking into account people’s needs (Dudley et al., 2005). The most important socio-economic requirements for reforestation success appear to be enhanced livelihood planning, active participation and involvement of local people, payment for environmental services provided by forests, socio-economic incentives, financial and economic viability, degree of dependency on traditional forest products, social equality, absence of corruption, marketing prospects, and addressing underlying causes of forest loss and degradation (Table 8).

4.2.1. *Livelihood planning*

Livelihood-enhancing activities must be part of reforestation plans (de Jong et al., 2006; Chokkalingam et al., 2006a), and projects developed should address the needs of people in the area in order to ensure their participation and interest in sustaining the project. Reforestation projects have often deprived people of their original livelihoods (such as food production and the collection of non-timber forest products on the land to be reforested), while not providing viable alternatives. Many cases were observed across the Philippines and Vietnam where the project beneficiaries subsequently burned the project area so that they could be reemployed in the process of replanting or reforestation (Chokkalingam et al., 2005). It is imperative to carry out a socio-economic analysis of promising production systems and small-scale trials before promoting them. Tree-based production systems that incorporate tree species with short harvesting cycles and good market prospects tend to be more widely adopted. Integrated production systems (e.g. agroforestry, livestock, and fish) can help increase food security and overcome market instability in forest products.

4.2.2. *Local participation and involvement*

Tree planting programs are most successful when local communities are involved and when the people perceive clearly that to achieve success is in their own interest. Nawir in CIFOR Rehab Team (2006) explains that “the projects which worked best in Indonesia were tailored to meet the needs of local communities”. A similar observation can be made from South American case studies, where “the lesson learned from the survey of Peruvian restoration schemes is that project managers need to ensure active local participation from the planning phase onwards” (Sabogal in CIFOR Rehab Team (2006)). In other words, reforestation projects should ensure strong community and stakeholder participation in planning, management, implementation, and continuous monitoring.

The most important impediment to community participation has been the half-hearted offers by reforestation projects to involve local communities in managing forests, which have caused unresolved problems and community disappointment (Nawir et al., 2007). Limited community participation can also be attributed to the unclear nature of economic incentives provided by reforestation projects, lack of consideration of social aspects in the project design and implementation, and not enough capacity building of community organisations (Nawir et al., 2007).

4.2.3. *Socio-economic incentives*

Unless direct economic or indirect incentives (including environmental and social services resulting from the reforestation programs) are provided to the local communities, their involvement is not likely to be sustained, and consequently the viability of reforestation programs will be reduced (Sayer et al., 2001). Chokkalingam et al. (2006a) found that in the Philippines, the long-term maintenance of plantations was positively related to planned socio-economic incentives.

4.2.4. *Economic and financial viability*

Unfortunately there is a tendency for authors who are not economically literate to use the terms ‘financial’ and ‘economic’ viability interchangeably, and this can lead to confusion. The term ‘financial’ refers to returns to the individual/company and financial viability is determined by discounted cash flow analysis undertaken from the perspective of the firm and is restricted to cash returns only. Economic viability is determined from the perspective of the community/society as a whole. A comprehensive economic analysis would also place a value on non-financial benefits such as environmental services and employment. Financial viability would be the appropriate metric for reforestation projects that are undertaken for a private benefit (i.e. a commercial timber production). Reforestation to restore degraded lands to reduce sediment flow into rivers, improve biodiversity etc. would seldom be financially viable but may be economically viable when the non-financial benefits are considered. Funding for reforestation projects by aid organisations is often given because they are not financially viable as commercial projects. Communities also want

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reforestation to improve water quality and for other environmental benefits. In these cases, where non-financial benefits are important, then the key is that reforestation doesn't impose a financial burden on the community and ideally also produces some financial benefits.

At the operational level, Chokkalingam et al. (2006a) found that the most common financial problems with reforestation projects in the Philippines were limited funding or poor access to funding, as well as delayed funding releases from the government. Projects with better financial support tended to be better maintained and protected. The timely releases of funds for reforestation projects is crucial because planting has to be done during the few wet months of the year, otherwise the risk of seedling death becomes high.

Reforestation is a long-term process and will generally require funding over many years, ideally until income is generated from the forests that were planted. All too often, over-reliance on grants means that funds can only be obtained for short-term projects. Chokkalingam et al. (2006a) suggested that it is better not to rely totally on short-term government and foreign aid funding, although this is good as start-up money for site development and social organising. Projects should have long-term income generation and reinvestment plans from forest products or from livelihood schemes (Chokkalingam et al., 2006a).

4.2.5. *Payments for environmental services (PES) schemes*

Because of the dramatic loss in forest cover worldwide, and the consequent loss in forest goods and services, there is potential to incorporate payments for environmental services into reforestation projects (Landell-Mills and Porras, 2002; Schuyt, 2005). The types of goods and services that restored forests can provide, and that can be quantified, include payments for carbon sequestration, watershed protection and biodiversity conservation. Reforestation is expensive, particularly in the initial stages and payments for the supply of environmental services may be especially important for improving the financial viability of reforestation (Pagiola et al., 2002; Rietbergen-McCracken et al., 2007).

4.2.6. *Social equity*

For reforestation projects to be successful, market and non-market costs and benefits need to be shared by all stakeholders. The inadequate assessment and sharing of costs and benefits arising from reforestation projects can result in community conflict and further deforestation (ITTO, 2002). Local communities are entitled to share in both the market and non-market benefits arising from reforestation activities on their land, and, equally, they are entitled to compensation for any third-party reforestation activities that negatively affect them.

4.2.7. *Corruption*

Corruption can play a large role in the success or failure of reforestation projects (Dudley and Aldrich, 2006; de Jong, 2008). Funds available for reforestation can be quickly absorbed by corruption, leaving little money for on-ground reforestation activities. Corruption can also result in a lack of participation of local people in reforestation projects and a lack of project support.

Table 8
Socio-economic drivers.

Drivers	Comments	Examples from literature
Livelihood planning	Livelihood-enhancing activities must be part of the plan, livelihood projects as a part of the overall plan should address the needs of people in the area in order to ensure their participation and interest in sustaining the project.	de Jong et al. (2006); Chokkalingam et al. (2006a)
Local participation and involvement	Active participation of the key actors taking into account local knowledge and practice is essential for sustaining reforestation projects.	Ramakrishnan et al. (1994); Morris (1997); Sayer et al. (2001); ITTO (2002); Lamb and Gilmour (2003); Chokkalingam et al. (2005)
Socio-economic incentives	Unless direct economic or indirect incentives (including any environmental and social services resulting from the reforestation programs) are provided to the local communities, their involvement is not likely to be sustained, and consequently the viability of reforestation programs will be reduced.	Sayer et al. (2001); Chokkalingam et al. (2006a)
Financial and economic viability	Efforts to rehabilitate degraded forest land can only be sustainable if reforestation projects are economically or financially viable.	Ramakrishnan et al. (1994); ITTO (2002)
Payments for environmental services (PES) scheme	The opportunities from PES for reforestation are potentially enormous. Reforestation might be more attractive to landowners if they are paid for the ecological services provided to those who benefit from reforestation but who share neither the costs nor risks.	Landell-Mills and Porras (2002); Pagiola et al. (2002); Lamb et al. (2005); Schuyt (2005); Rietbergen-McCracken et al. (2007)
Social equity	All stakeholders' participation is necessary for reforestation and management strategies to be effective and successful.	Ramakrishnan et al. (1994); ITTO (2002)
Corruption	Corruption can play a large role in the success or failure of reforestation projects.	Dudley and Aldrich (2006); de Jong (2008)
Degree of dependency on traditional forest products	Reforestation is more likely if the supply of valued forest goods (such as medical plants) from natural forests is declining and there are no alternative supplies.	Lise (2000); Rietbergen-McCracken et al. (2007)
Marketing prospects	Good market prospects and marketing plans led to good production outcomes for reforestation projects, and provide incentives for local people participating in reforestation projects.	Amacher et al. (1993); Dewees (1995); Scherr (1995); Mercer and Pattanayak (2003); Harrison et al. (2004); Chokkalingam et al. (2006a); (Chokkalingam et al., 2006b); Snelder and Lasco (2008);
Knowledge of markets for timber and other forest products and services	Reforestation is easier if there is a known market (and especially an improving market) for forest goods and services, particularly if further supplies from natural forests are unavailable.	Rietbergen-McCracken et al. (2007)
Addressing underlying causes of forest loss and degradation	Addressing causes of forest loss and degradation is important to ensure reforestation success.	Chokkalingam et al. (2006b); Nawir et al. (2007)

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4.2.8. Degree of dependency on traditional forest products

Forest dependency stimulates people's participation in forest management; a higher level of forest dependence means that the people have a higher stake in the forest, which is reflected in their level of participation (Lise, 2000). Reforestation is more likely to be successful if reforestation projects supply valued forest goods (such as medicinal plants) that cannot be obtained from elsewhere (Rietbergen-McCracken et al., 2007).

4.2.9. Marketing prospects

The marketing success of forest products is influenced by the species planted, the project location and the staging of the project to ensure continual supply of forest products to customers (Harrison et al., 2004). In the Philippines, the marketing of forest products is typically not included in government reforestation projects (Snelder and Lasco, 2008). It seems that insufficient consideration is often given to final products because harvest, which is generally more than 10 years from the time of planting, is generally outside the typical funding horizon of three to five years. Both household demand and prevailing market conditions for timber and non-timber forest products influence the success of reforestation projects. For example, implementing a reforestation project in an area that has low excess demand for forest products may lead to oversupply, driving forest product prices down and undermining the economic viability of the project (Dewees and Saxena, 1997). However, supply in excess of local demand also creates the opportunity for new livelihood opportunities based around excess timber (e.g. additional sawmilling, value adding activities such as furniture making and biofuel). Unfortunately, little information is available on the size and stability of the markets for timber and non-timber forest products in rural regions of developing countries.

When good markets exist for products such as poles, firewood and fruit, farmers have an incentive to plant trees (Amacher et al., 1993; Dewees, 1995; Scherr, 1995; Mercer and Pattanayak, 2003). Where the areas being rehabilitated are isolated from markets, the harvested products should be of sufficient value to permit long distance transport (Lamb and Tomlinson, 1994), or alternatively, local processing/value adding needs to occur.

Knowledge of markets for timber and other forest products and services is also important to the success of reforestation. A known market (and especially an improving market) for forest goods and services will lead to a greater incentive among local communities to plant trees, especially if no supplies from natural forests are available (Rietbergen-McCracken et al., 2007).

4.2.10. Addressing underlying causes of forest loss and degradation

Sites targeted for reforestation in the tropics are usually under pressure from logging, fuelwood collection, grazing and shifting cultivation. It is therefore important to address these causes of forest loss and degradation to ensure the success reforestation (Nawir et al., 2007). Alternative fuel sources can be solutions to reduce pressures on re-growing forests (Chokkalingam et al., 2006b).

4.3. Institutional, policy and management success drivers

There is a multitude of institutional, policy and management success drivers reported in the literature (Table 9). Commonly reported drivers include strong and appropriate institutional support, effective forest governance, a stable policy environment and strong support for forest production, secure land tenure and equitable land tenure systems, clear conflict resolution mechanisms, clear distribution of rights and responsibilities amongst stakeholders, long-term management planning, long-term maintenance and protection of reforested sites, forestry support programs, presence of community organisers and people's organisations, strong local leadership to enforce collective rules, and risk involved.

The World Bank Forest Strategy (Lele et al., 2000) reported a strong difference in the forest management policies of forest-rich and forest-poor countries. They found that forest-rich countries (such as Brazil,

Table 9
Institutional, policy and management drivers.

Drivers	Comments	Examples from literature
Institutional arrangements	Strong and appropriate institutional support is critical for promoting investment and local participation in reforestation projects, and ensuring their sustainability.	Chokkalingam et al. (2005); Chokkalingam et al. (2006a); Chokkalingam et al. (2006b)
Effective governance	Reforestation can only succeed if forest governance is effective.	ITTO (2002); Dudley and Aldrich (2006)
Forest harvesting polices and other forest policies	Unstable policy environment and poor support for forest production affects the long-term sustainable management of forests, especially by communities and the private sectors.	FMB-FAO (2003)
Tenure security	Secure land tenure, land-user access, customary rights and property rights are fundamental to reforestation success.	Bromley (1992); Ramakrishnan et al. (1994); Zhang and Pearse (1997); Place and Otsuka (2000); Treue (2001); ITTO (2002); Chokkalingam et al. (2005)
Conflict resolution mechanism	The lack of a clear conflict resolution mechanism has led to greater social unrest at sites to be rehabilitated.	Chokkalingam et al. (2006a); Chokkalingam et al. (2006b); Nawir et al. (2007)
Distribution of rights and responsibilities amongst stakeholders	In practice, rights and responsibilities allocated in an unclear manner have frequently triggered conflicts of interest during the long period over which reforestation projects are implemented.	Nawir et al. (2007)
Long-term management planning	Reforestation success depends on wise planning, both in time and in space, balancing short-term with long-term goals, and allocating the funding available for the reforestation project as efficiently as possible.	Vallauri et al. (2005); Chokkalingam et al. (2006a)
Long-term maintenance and protection of reforested sites	Primary causes of reforestation failure, other than inappropriate technologies, are uncontrolled grazing and fires, competition from weeds, and uncontrolled cutting for fuel, fodder, and lumber.	Shen and Hess (1983); Chokkalingam et al. (2006a); de Jong et al. (2006); Nawir et al. (2007)
Forestry support programs	Forestry support programs like technical assistance and training are a key incentive for adopting community-based forest management.	Austria (1995); Hartanto et al. (2002); Calderon and Nawir (2006); Baynes et al. (in press)
Presence of community organiser and people organisations	Community organising is one of the major activities that enable active community participation in forest development and protection	Emtage (2004); Estoria et al.(2004); Chokkalingam et al. (2005); Dolisca et al. (2006)
Community leadership	An important socio-economic requirement for reforestation success is strong leadership	Lamb (1988); Karki (1991); FAO (1993)

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Cameroon, and Indonesia) have sought to exploit their forests for development purposes, as well as for the benefit of powerful interest groups, and as a result deforestation rates have not been reduced. In contrast, some forest-poor countries (such as China, Costa Rica, and India) have addressed forest conservation and have incorporated forest concerns into overall development planning to alleviate poverty while minimising the loss of forest cover and biodiversity. Lele et al. (2000) concluded that independent of the World Bank Forest Strategy, forest scarcities have brought about conservation-oriented policies in the forest-poor countries and the forest-poor regions of forest-rich countries (for example, southern Brazil). This highlights the role of tree scarcity in influencing the development of policies that conserve forest and support reforestation.

4.3.1. Institutional arrangements

Forestry legislation, a forestry code, and non-formal taboos that affect how people use forest resources are all examples of institutional arrangements within the forestry sector. Strong and appropriate institutional support is critical for promoting investment and local participation in reforestation projects, and ensuring their sustainability (Chokkalingam et al., 2005). This includes clear and undisputed land tenure, a facilitating legal framework and policies, and coordination among agencies at various levels. Also important are formalised institutional arrangements with clear division of tasks, rights and responsibilities, equitable distribution of costs and benefits among multiple stakeholders, and a clear conflict resolution mechanism (Nawir et al., 2007). These arrangements help to avoid conflicts, support coordinated project management and fulfilment of assigned tasks, and ensure agreed-upon benefit flows to stakeholders and their stake in the long-term success of the project. Enforcement of agreements is an important part of such institutional arrangements.

4.3.2. Effective governance

Governance denotes “the process of decision-making and the process by which decisions are implemented (or not implemented)” (UNESCAP, 2009:1). Good governance is a term used in development literature to describe how public institutions conduct public affairs and manage public resources in order to guarantee the realisation of human rights (UNESCAP, 2009).

Governments make decisions and implement these through the administration of state resources and use of market mechanisms. Governance also involves working with other governments and with the private sectors, including community organisations. Major characteristics of good governance are rule of law, responsiveness, transparency, effectiveness and efficiency, consensus orientation, participation, equity and inclusiveness and accountability (Dudley and Aldrich, 2006).

Reforestation can only succeed if forest governance is effective (ITTO, 2002). It is much easier for reforestation projects to be successful in conditions where there is good governance and lack of corruption (Dudley and Aldrich, 2006). Effective governance is a pre-requisite to promote the sustainable management and use of forests and to prevent further degradation and inappropriate conversion to other land uses. This requires national policies and legal measures, appropriate economic governance and incentives and appropriate institutional frameworks to support reforestation and associated livelihood projects.

4.3.3. Forest harvesting policies and other forest policies

Clear and consistent policies are required for management and harvesting in forestland with various types of legal status, tenure and institutional arrangements (such as watersheds, protected areas and community-based forestry management areas). Unstable policy environments and weak support for forest production will affect the long-term sustainable management of reforestation projects, especially by communities and the private sectors (FMB-FAO, 2003).

In the Philippines, Chokkalingam et al. (2006a) found that a Presidential Decree was in place banning timber harvesting in critical watersheds containing infrastructure such as hydro-power plants and irrigation systems, whilst at the same time a Letter of Intent allowing timber harvesting within these same areas was in place. This made it difficult for reforestation projects to obtain permits to harvest in critical watershed sites despite timber marketing being approved in their initial reforestation and area development plans.

4.3.4. Tenure security

Unless rights and responsibilities of tenure are clearly defined and understood by all the participants, reforestation is not likely to succeed (Ramakrishnan et al., 1994). Secure land tenure and land-user access are fundamental to reforestation success (ITTO, 2002). Tenure security both over the land and its resources will go a long way towards ensuring long-term management interest and investment of effort by farmers and communities in reforestation (Chokkalingam et al., 2006a). Land users are only likely to participate in reforestation if they or their families will benefit (Fortmann and Bruce, 1988; Rietbergen-McCracken et al., 2007). This is unlikely if they have insecure tenure. Reforestation that results in reduced access to land that is currently available will be unattractive unless some form of compensation is available (Rietbergen-McCracken et al., 2007).

Clear land tenure to enable the sustainable management and use of rehabilitated forests need to be in place in order to prevent further degradation and inappropriate conversion to other land uses. In many cases, degraded forests have overlapping tenure claims involving the state, private sector and local communities. As a result, conflicts over access rights are common, often resulting in unsustainable use and further degradation of the resource. Clear land tenure means less conflict over land, a high commitment by the community to maintain the trees planted and an assurance to community members that they will be able to harvest the trees that they have planted on their land (Sellers, 1988; Pasicolan et al., 1997; Zhang and Pearse, 1997; Treue, 2001; Herbohn et al., 2005).

4.3.5. Long-term management planning and maintenance

Proper care and maintenance of reforestation sites is needed until forests are self-maintaining (if planted for conservation purposes) or reach a harvestable age if trees are planted for commercial purposes. The main causes of reforestation failure, other than inappropriate technologies, are uncontrolled grazing and fires, competition from weeds, and uncontrolled cutting for fuel, fodder, poles and lumber. Therefore, continued management and protection are important factors for maintaining planted areas in the long-term (Chokkalingam et al., 2006a).

Long-term management planning has been a relatively neglected aspect of reforestation activities, especially after funding for a reforestation project has ended. Vallauri et al. (2005) stated that plans were often lacking in past-reforestation projects, especially site-oriented ones, and this had led to many failures and difficulties that often emerged only decades after the reforestation efforts had begun. In the Philippines, Chokkalingam et al. (2006a) found that inadequate long-term planning had caused forest conversion to other land uses and forest fires. Chokkalingam et al. (2006a) also found that having a management plan was positively correlated with the long-term maintenance and protection of reforestation projects and proposed three indicators for assessing the sustainability of project management: the existence of a long-term management plan, having a plan for long-term monitoring and evaluation, and having a feedback mechanism.

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4.3.6. Forestry support programs

The availability of forestry and agroforestry extension services and the dissemination of forest management information are essential in improving the success of reforestation. The frequency with which farmers have contact with extension agents is important in the acquisition of skills and knowledge (Salam et al., 2000; Adesina and Chianu, 2002). Hence, the efficiency of the forestry/agroforestry extension services and dissemination of information is essential in improving farmers' forest management capability. Technical assistance and training are key incentives for adopting community-based forest management (Borlagdan et al., 2001). Baynes et al. (in press) found that in the Philippines, extended extension assistance was crucial in determining the likely survival and growth of trees. Extended extension assistance was also important for eliminating unsuitable sites and the use of poor forest establishment practices. Where extension support was not available, farmers displayed a poor knowledge of the principles of tree growth (Baynes et al., in press).

Besides providing extension services, government and non-government agencies can play a critical role in providing marketing support for timber and other products generated by farmers, communities and the private sector to sustain investment in reforestation. Community-based market information systems, selecting species based on markets, incentives to processing firms to obtain wood from reforested areas, forming marketing associations, improving roads and transport and certification have all been suggested as means to improve marketing (Austria, 1995; Hartanto et al., 2002; Calderon and Nawir, 2006).

4.3.7. Presence of community organisers and people's organisations

Community organising is one of the major activities that enable active community participation in forest development and protection (Estoria et al., 2004; Chokkalingam et al., 2005). Community organisers are employed to help establish and maintain people's organisations and are critical in assisting the community organisations to comply with their forestry contracts. The role of community organisers includes facilitating the formation of people's organisations and providing advice about the preparation of the plans and applications for permits required to establish and later harvest planted areas. Community organisers also help to build the capacity of communities to establish sustainable enterprises and livelihood projects designed to provide participants with immediate income (Emtage, 2004), and to grow trees and protect forests for the future (Estoria et al., 2004). Estoria et al. (2004) found that community organisers were a major influential factor in the success of reforestation activities in the Philippines. A good community organiser contributed greatly to a project's success. Conversely, the lack of attention given to community organising has been identified as a factor hindering reforestation success.

A well-organised group has a greater probability of succeeding, particularly during the phases of product harvesting, processing and commercialisation. Numerous positive and negative cases exemplifying this lesson exist across the Peruvian and Brazilian Amazon, the Philippines and Indonesia (Chokkalingam et al., 2005). Strong people's organisations can also attract support from international NGOs for livelihood programs (Chokkalingam et al., 2005).

4.3.8. Community leadership

Strong leadership is an important requirement for reforestation success. The FAO (1993) found that strong village leadership was instrumental in getting reforestation started in Peru. Unilateral decision-making by leaders was, however, usually not sufficient to reduce underlying resistance from the community-at-large. In some cases, it may have exacerbated opposition to reforestation. Furthermore, the concentration of power and knowledge of legal procedures in the hands of a few sometimes appeared to encourage abuse and even corruption. This, in turn, increased opposition to further reforestation (FAO, 1993).

4.3.9. Risk involved

Low-cost reforestation (such as promoting natural regeneration) is likely to be less risky to farmers than higher-cost methods (such as plantation establishment). This is because where the costs of forest establishment are high, farmers risk to lose more if their trees are destroyed by adverse weather events or if the market prices for forest products falls significantly. Similarly, fast-growing species are usually more attractive than slow-growing species, because the financial returns occur sooner and the risks caused by adverse weather events are reduced due to shorter rotations lengths. Financial incentives or subsidies (such as low interest rate loans) can reduce the risk to local people being involved in reforestation projects and improve participation (Rietbergen-McCracken et al., 2007).

4.4. Reforestation project characteristics

Besides the biophysical, technical, socio-economic, institutional and political environment surrounding reforestation projects, characteristics of projects themselves have been found to influence success (Belassi and Tukel, 1996). These include objectives and goals of the project, the size of the project, location of the project, project funding, type of project implementer, and the project life cycle.

4.4.1. Reforestation goals and objectives

Reforestation experiences from the Philippines have shown that projects with economic production objectives have provided strong incentives for long-term management while pure conservation projects had little chance of success (Chokkalingam et al., 2006a). This suggests that producing timber is important for ensuring the long-term sustainability of reforestation projects by meeting the industrial and household demand for forest products, generating income for impoverished communities, and providing environmental services in the process (Chokkalingam et al., 2006a).

It is important to consider reforestation not in isolation from other conservation and development projects, but rather as an integral part of joint efforts to achieve sustainable ecosystems and landscapes. This implies better integration of reforestation projects with other plans and development projects, such as protected area selection, species conservation, water conservation and climate change mitigation.

4.4.2. Project location or accessibility of sites

The distance between a field and the farmer's house is negatively related to tree growing. Trees are preferably grown close to the house where farmers can more easily inspect them and prevent damage or losses by fire, animals and theft (Schuren and Snelder, 2008). Nawir et al. (2007) suggested reforestation success is higher on land close to human settlements as opposed to remote areas because the former is highly accessible, enabling continuous monitoring. Degraded sites that are difficult to access will be expensive to reforest and it may be too costly to do anything about such sites apart from using low-cost assisted natural regeneration (Rietbergen-McCracken et al., 2007).

4.4.3. Project implementers

The type of organisation implementing a reforestation project can have a large influence on success. Research by CIFOR in the Philippines found that the type of agency implementing a reforestation initiative influenced the approaches adopted and the outcomes of reforestation (Chokkalingam et al., 2006a).

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4.4.4. Reforestation on private versus public land

Whether reforestation occurs on public or private land can strongly influence the objectives of reforestation, the size of reforestation projects, and the relative importance of success drivers. Most reforestation projects undertaken on public land, for instance, are larger projects which have community livelihood and environmental benefits as key objectives, and therefore success is dependent on community support and external funding. However, a substantial area of reforestation in the tropics is implemented by farmers on private smallholdings of less than five hectares. For instance, in 2001 farm forestry accounted for 43 percent of the total forest plantation area in Indonesia, with 3.43 million households involved in managing 4.2 million hectares (FAO, 2001). In Vietnam, 80 000 ha have been reforested annually through farm forestry since 1998 (FAO, 2006a). On a global scale, small-scale farm forestry plantations (50 million hectares) nearly matched the area planted by state forestry agencies (77.3 million hectares) and are almost double the area of plantations established by corporate groups (27.2 million hectares) (FAO, 2006b).

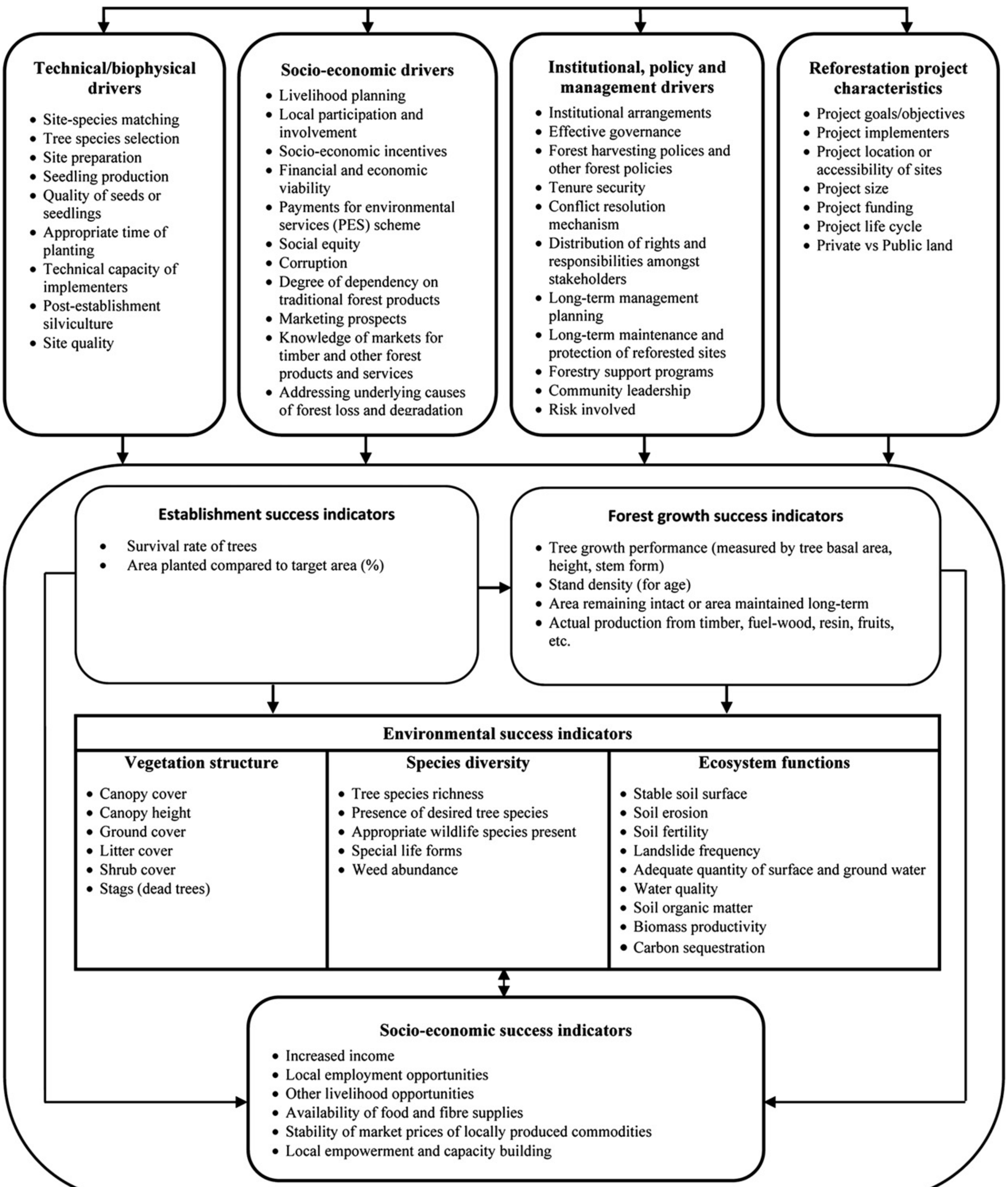

Fig. 1. Conceptual model for assessing reforestation success.

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In general, trees are often planted by farmers on private land for financial benefit and represent a conscious investment for which other options have been forfeited. These plantings are generally restricted to the number of trees that can be maintained and the available land, labour, and other resources are allocated according to the farmer's objectives. Smallholder tree plantations generally benefit from intensive management over small areas and vested self-interest (Roshetko et al., 2008). However, not all smallholder tree plantings are successful. Experience from the Philippines indicates that where smallholders do not have access to good quality seedlings and lack the basic knowledge of site-species matching and silvicultural techniques, smallholder plantings perform poorly or fail (Baynes et al., in press).

4.4.5. Project funding

Most externally funded reforestation projects are not commercial ventures and are planted for environmental and local community benefits. These projects are reliant on government and NGO funding rather than private investment. Access to government funding and the longevity of government funding can therefore be an important driver of project success. For projects that are not externally funded, such as plantings on smallholder farms, the availability of funding is also important to support extension and education services that in turn influence the management of these plantings and their eventual success.

5. A conceptual model for assessing reforestation success

From the literature it is clear that planning for and assessing reforestation success is complex. There are several stages in the reforestation process to consider, several objectives and a multitude of indicators and drivers. Due to the idiosyncrasies of individual reforestation projects, it may not be possible to develop an integrated reforestation planning and evaluation model that captures all drivers of success. However, based on our description of reforestation success, and a review of the indicators and success drivers, we propose a general conceptual model that captures indicators and drivers that would be relevant to planning or assessing a broad range of reforestation projects in tropical developing countries (Fig. 1).

The conceptual model consists of four main groups of indicators, including establishment success indicators, forest growth success indicators, environmental success indicators, and socio-economic success indicators. These indicators are not independent. For instance in Fig. 1, establishment success influences forest growth success, and establishment and forest growth success influence environmental success. Socio-economic success is dependent on establishment success, forest growth success and environmental success.

Each group of indicators is influenced by multiple success drivers. These success drivers are grouped into technical/biophysical drivers; socio-economic drivers; institutional, policy and management drivers; and reforestation project characteristics. There may also be dependencies among these success drivers, however, the relative influence of drivers on one another and the relative influence of drivers on success indicators will vary and that is why individual drivers have not been linked to individual indicators in the conceptual model.

6. Discussion and conclusions

It is clear from a review of examples of reforestation assessments published in the formal scientific literature that there are two key deficiencies in current reforestation project assessments. These are 1) a narrow focus on the early stages of projects, and 2) the limited considerations of drivers of success. There are scant examples of reforestation assessments that comprehensively cover all of the main stages in reforestation projects (including forest establishment, growth and maturation) as well as the main dimensions or objectives of reforestation (tree performance, environmental success and socio-economic success). There are a number of reasons for this. Typically reforestation programs in developing countries are funded by foreign donors (e.g. intergovernmental aid; conservation and development focused NGOs) and implemented by either local NGOs or government departments. As such, if assessments are undertaken, then they are narrowly based on criteria set by the funding agency. These criteria are usually metrics associated with ensuring that the funding has been applied in the manner intended rather than broader, longer-term outcomes, hence they are generally focused on simple criteria, such as area planted and initial tree survival, and generally focused on the short-term stages of projects. The typical funding time frame for reforestation is three to five years and the metrics for assessment reflect this short time frame, that is, establishment and early growth. In addition, funding is generally provided to facilitate reforestation for a specific goal such as biodiversity restoration or timber production. In these cases, the metrics used for assessment tend to be restricted to those directly related to biophysical objectives (e.g. tree species richness, presence of desired species) while broader criteria for longer-term success and sustainability (e.g. increased income, local employment opportunities) are ignored. In addition, formal critical assessments of reforestation programs are often either not undertaken or not reported in the scientific literature because the implementers (e.g. government agencies and local NGOs) are only concerned about satisfying donor requirements for reporting. Also, it is in the self-interest of implementing agencies to avoid publishing data that reflects poor performance for fear of the potential for reductions in current or future funding.

It is also evident that the drivers of reforestation success are ignored in the majority of reforestation assessments. Assessments generally focus on success indicators without delving into the factors that may be influencing good or poor performance. These success drivers span an array of biophysical, socio-economic, institutional and project characteristics. Without considering these success drivers, it will be difficult, if not impossible, to identify the reasons for the success or failure of projects, to learn from past mistakes, or to design interventions needed to improve the success of current and future projects. Looking at success drivers is particularly important for designing future projects because if the project is not designed to maximise the potential for success within the environment it is being implemented, then it will be at risk of failing right from the beginning. Therefore, a fundamental shift is needed away from continual reporting against success indicators, to a serious consideration of project design and risk management through interventions that maximise the chances of project success.

It is clear from the literature that there is a complex array of drivers and indicators involved in assessing reforestation success and that these interact, so cannot be considered in isolation from each other. As a result, in order to improve reforestation project success it is necessary to understand these interactions and the systemic influence that drivers have on reforestation success. Therefore, a systems approach to reforestation planning and evaluation is needed. This means utilising systems thinking and modelling tools to relate drivers and indicators and understand how a change in one driver may influence other drivers and indicators, as well as the relative influence of drivers on indicators. Systems theory and tools can provide a way forward in the development of integrated reforestation assessment. They have been widely applied to assist in understanding complex social, economic

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and environmental systems (Clayton and Radcliffe, 1996; Bellamy et al., 2001) by relating both ecological and socio-economic components (Mansourian et al., 2005b).

Most policy makers and staff within the government and NGO funding agencies seldom access information in the formal scientific literature. The challenge to improving reforestation success is to find ways in which to engage with this key group. In its current form, the conceptual model for assessing reforestation success presented in this paper can be used as an education tool, particularly to demonstrate the complex multidimensional nature of reforestation to policy makers and funding agencies. In addition, the conceptual model is a first step towards a formal systems-based reforestation assessment approach. It identifies sets of drivers and indicators and their broad relationships, however, the next step will be to identify detailed relationships between drivers and indicators and to quantify these. Developing quantitative systems models for reforestation assessment will be a challenging task because the modelling tools used will need to 1) combine quantitative and qualitative drivers and indicators, 2) integrate quantitative data and expert opinion, 3) accommodate uncertainty and knowledge gaps, 4) provide scenario and sensitivity analysis capability so that project design and interventions can be tested, and 5) be intuitive enough to facilitate communication among stakeholders and policy makers regarding project design and intervention requirements. The models will also need to support adaptive management of reforestation projects because unforeseen circumstances and knowledge gaps may mean that our understanding of what influences reforestation success, and the relative influence of drivers on success, changes over time. This means that the models will need to be amenable to updating as new knowledge accumulates (Rumpff et al., 2011).

There are a number of approaches and tools available for developing systems models, all with strengths and weaknesses (see Liedloff and Smith, 2010 for example). The authors are currently investigating the application of Bayesian networks as an appropriate system modelling tool, as they have been used previously to build system models that integrate qualitative and quantitative variables, integrate knowledge, accommodate uncertainty in decision-making, conduct scenario analysis and support adaptive management (Smith et al., 2007; Uusitalo, 2007; Rumpff et al., 2011).

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