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Forest Production, Restoration and Management under Climate Change

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ABSTRACT

Many countries in the world are faced with two diverse but interwoven challenges in the 21st century; feeding a growing population and how to adapt to climate change. Changes in climate are recognized as one of the major factors accelerating the degradation of land. Thus, land degradation either caused by human being or natural factors is still a continuous process and the coverage of forests is dwindling. To halt the problem successful, restoration of forest ecosystems using native species as healthy living systems, capable of adaptation climate change requires attention. At the establishment phase, tree selection for rehabilitation however, remains one of the least understood and most often ignored components where rehabilitation has been done by using exotic tree species. Therefore, to achieve the successful rehabilitation of degraded lands, foresters and nursery managers need to reconsider the selection, production, and out planting of native trees in a dynamic context instead of the monoculture exotic plantation to create connectivity across landscapes and building in adaptability for changing climates.

INTRODUCTION

Forest resources across the world have been increasingly degraded and the rest stressed over the past two decades mainly due to the factors related with population growth and climate change. Global total forest area decreased from 4.28 billion hectares to 3.99 billion hectares from 1990 to 2015, with percent global forest cover dropping from 31.85% to 30.85% (Payn et al., 2015). Thus, understanding of the complex relationships between a changing climate, forests and its management is important for the sustainability of life on the earth.

Climate change could have significant negative impacts on existing forests (Sedjo & Sohngen, 1998); on nursery production by heat stress damage, high day and soil temperature, increasing the water take up and transpiration (Burton, 2016); and also failures of

survival of newly planted seedlings (Paterson et al., 2015). It presents significant potential risks to forests and challenges for forest managers (Keenan, 2015). On the other hand, increasing demands of forest products and services caused by high population growth is also resulting a serious pressure on the area, quality of forest resources. In the 1800th the world population was 1 billion (Mittal and Mittal, 2013), and after 2 centuries later, the global population is 7.6 billion, which is expected to reach 8.6 billion in 2030 (UN, 2017).

Survival of planted trees is an attribute of the quality of planting seedlings used (Nyoka et al., 2018). Production of healthy trees seedlings (both genetically and physical condition) is one of the key solution to halt deforestation and sustainability of forest resources. Because, tree growth is a function of genetic potential of the species and environmental conditions (Koslowski et al., 1991). However, shortage of quality tree seedlings has been a major constraint in forestry and forest production. For instance, for the survival of seedlings, root growth potential (RGP) which is the ability to regenerate new roots and is closely linked to the seedling's ability to avoid water stress after planting is important (Duryea & McClain, 1984; McTague & Tiius, 1996). But, the environmental changes resulted from climate change is limiting the potential of plants to grow, reproduce and indeed survive through its life cycle (Martin, 2009). Present synthesis is an attempt to compile existing information on the forest production and management under the changing climate; impacts of climate on the rehabilitation process, survival of seedlings, and approaches for the sustainable management of forests including choices of species for the forest production and development.

Tree Nursery Production for Restoration and Climate Change

The climate appears to be changing faster than plants can adapt (Williams and Dumroese, 2014). Thus, the concept and understanding of climate change together with the problem it poses at present and future, is taken seriously across the world. Climate change is affecting forests though effects on nursery, weeds, soils, insects, invasive species and disease. In terms of nursery production the main climatic variables that are important includes temperature, solar radiation, water, and atmospheric CO_2 concentration. As plant growth is driven by environmental factors, any change to the environment will impact on production of plants specifically tree nursery.

Tree nurseries are vital to the existence and well-being of our environment to live in. Beside to being a source of employment for the societies, tree nurseries are the main sources of healthy seedlings. Thus, cultivation according to physiological guidelines is essential to produce plants with maximum survival and growth potential (Lavender, 1984). Actually, the production and growth of seedlings depends on the environmental condition. For instance, successful seedling establishment and growth depends on the soil condition and the stored soil moisture to ensure survival into the next growing season (Warren et al., 2005). Environmental factors such as light, moisture, nutrients, density, and temperature and plant physiological factors such as carbohydrate reserves, hormone levels, frost hardiness, and dormancy interact to shape growth and survival of seedlings in nursery fields and after out planting (Lavender, 1984). Therefore, in the nursery the production of trees which survive is considered more important and more likely to succeed than trying to influence the long-term growth of the stand (Donald, 1979).

In recent years the attention of ecologists, researchers and scientists given to the impact of climate change on the forests and the management strategies aimed at assisting forests to adapt to climate change. However, it's seldom observed that implementation of these strategies to the sources of forest plants specifically tree nursery production. The increasing severity of climate impacts and vulnerability of forest ecosystem mean that the sources of planting materials to maintain the sustainability of forest and its management need more attention. Thus, we need to develop a range of flexible strategies to ensure sufficient volume of planting materials (Broadhurst et al., 2016); to give a wider recognition throughout the industry and meet the planting objectives sustainably (Whittet et al., 2016).

Artificial Regeneration of Degraded Lands, Seedlings Survival and Climate Change

Forest degradation is the most critical environmental problems in the 21st century. Although the biggest deforestation was made in the 20th century, it's still increasing worryingly (Kest, 2015). Human footprint has affected 83% of the global terrestrial land surface (Sanderson et al., 2002). In addition to the deforestation, both natural and plantation forest are facing challenges of climate change, increased demand, and damage by pests and diseases (Ennosa et al., 2019). As a result, approximately 60% of the services that support life on Earth are being degraded or used unsustainably (Hassan R et al., 2005). To reverse the effects of deforestation, restoration determinations have expanded the efforts and humankind is experiencing historical momentum that favors forest restoration (Shimamoto et al., 2018 and Jacobs et al., 2015); however, restoration and/or regeneration of degraded land is a major challenging issue due to exacerbated current climate change.

International conventions and national policies for biodiversity conservation and climate change mitigation state the need for increased forest protection, forest restoration and adaptation of forest management to climate change (Löf et al., 2019). For the success of the convention and policies of rehabilitation of degraded lands, tree seedlings are important as they are the foundation of many terrestrial ecosystem (Haase, 2018). Thus, foresters and nursery managers will need to reconsider the selection, production, and out planting of native trees in a dynamic context (Williams & Dumroese, 2014). As a solution to forest degradation, millions of hectares of land to be restored worldwide in the century, planting

of seedlings or natural rehabilitation is required.

An artificial regeneration is a method of recovering and/or afforesting degraded or lifeless land by human intervention such as planting, sowing or other artificial methods. Whereas, the natural regeneration is achieved by a passive method where regeneration of degraded land taken place by gradual processes. Artificial regeneration method is needed for regulated species composition, quick results, and better yield. However, it's relatively expensive method of rehabilitation of degraded land (Moreira et al., 2009). On top of its expensiveness, harsh environmental condition results an impediments to the establishment and survival of forest trees in degraded lands (Uhl, 1988).

Literatures state that nursery cultural, health of seedlings and silvicultural practices have a strong influence on seedling performance immediately after planting (Grossnickle, 2012 and Mathers et al., 2007). However, the potential of young seedlings to adapt to the new environment and the influence of the surrounding environmental condition are more severe in influencing the survival. For instance, the extreme drought or heavy freezing of the ground immediately after planting are another factors influencing the survival of young seedlings. As the seedlings are transplanted from their source of origin; nursery, where there's care and treatment (Krishnan et al., 2014), exposing them to the new environment might result in survival failure problem. In this case, the capacity of newly planted seedlings initiate growth and become coupled into the forest ecosystem, thereby avoiding water stress are critical factors for success of a forest restoration program (Grossnickle 2005a). On the other hand, climate change is another factor in influencing the survival of recently planted seedlings. Depending on the region and emission scenario, changes in temperature and precipitation are expected to reduce habitat suitability for species (Phillips et al., 2018). Habitat suitability could be related with change in precipitation, temperature, water stress, invasive species, competition and related factors which influence the survival of seedlings.

Choice of Species for successful Forest Rehabilitation in the changing climate

Restoration and rehabilitation of degraded forest has been highlighted as an important intervention for climate mitigation because the carbon storage potential by reducing the vulnerability to the climate change (Locatelli et al., 2015). However, the choice of plantation species is likely to greatly influence both the rate and trajectory of rehabilitation processes (Parrotta, 1992). Mainly in the developing countries there is a lack of successful selection of species adapted to local conditions (Lu et al., 2017). For instance, countries in Africa and Europe the fast growing exotic species like Eucalyptus, Sitka spruce, and grand fir are introduced and promoted for their economic benefits. However, promotion of non-native tree species can also create new ecological risks, negative effect on the nature conservation, affect management and attention to indigenous trees, and lead to loss of biodiversity (Solomon and Moon, 2018; Hasenauer et al., 2017; Hughes, 1994 and Roy et al., 2012).

In fact the rehabilitation and survival or species success depends on plantation site quality (Pedraza and Williams-Linera, 2003), there is a need to develop or use a type of framework for appropriate selection of the most suitable multipurpose species (Reubens et al., 2011). Because, restoration, rehabilitation, reforestation and general forest plantations projects are undertaken for a variety of environmental, economic and social objectives (Simula et al., 2011). Also, rehabilitation of degraded land requires recognition of the place of forests in the culture of each society to integrate the rehabilitation and rural development (Lamb & Tomlinson, 1994). Furthermore, this is required to develop responsibility in between the society and so as to develop the approach of participatory forest management (PFM).

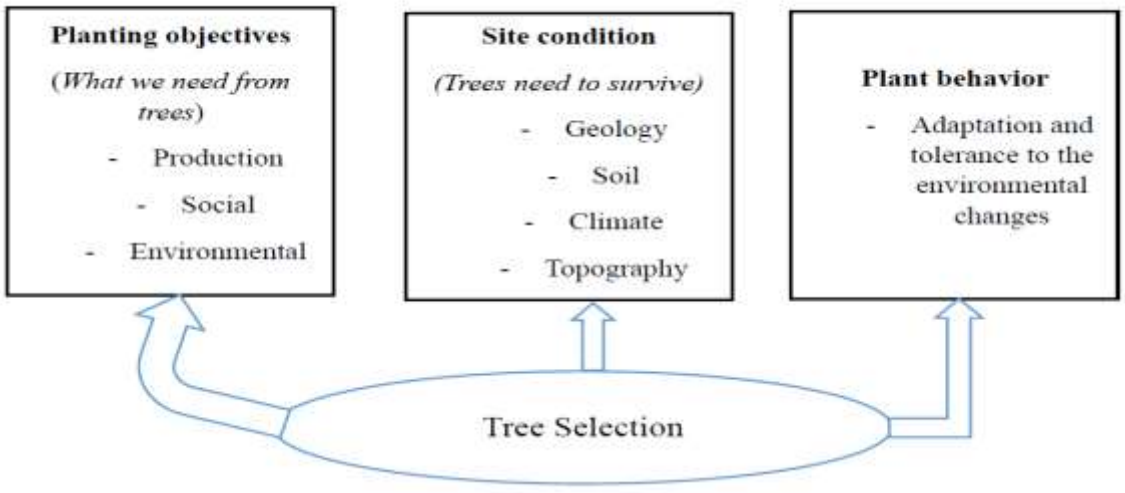

Figure 1: Criteria for the selection of trees for the rehabilitation of degraded lands (FAO, 1999; Burley, 1980)

Degradation of land is a worldwide problem that is caused by human activity (Sarah and Zonana, 2015). Changes in climate are recognized as one of the major factors responsible for land degradation (Kumar and Das, 2014). Climate change presents a significant potential risks to forests and challenges for forest managers (Keenan, 2015). Moreover, the current climate change scenarios predicts significant changes to regional rainfall and storm patterns (IPCC, 2007). Because, global mean surface temperature has increased, showing a warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012 (IPCC, 2017). Thus, as the land degradation either caused by human being or natural is continues process, the continuity and severity of the problem is unquestionable. Therefore, rehabilitation and restoration of forest ecosystems are in growing demand to tackle climate change, biodiversity loss and desertification major environmental problems of our time (Thomas et al., 2014). For the success of rehabilitation of degraded land, monoculture plantation should focus on multipurpose of the forests thereby to supply products and/or services with the reference of natural forests values (Kobayashi, 2007).

Planting Exotic Species for Rehabilitation of Degraded Lands: Solution or a Problem?

The challenge for ecologists, foresters, scientists and environmentalists is developing or establishing environmentally friendly, socially acceptable, economically viable as well as biologically sustainable planted forests. However, few attempts have been made to evaluate the costs and benefits of restoration interventions even though this information is relevant to orient decision making in policy of the land restoration (Schiappacasse et al., 2012). For instance, monocultures of exotic timber species (e.g., *Acacia, Eucalyptus, Pinus, Paraserianthes falcataria, and Gmelina arborea*) continue to be favored in commercial plantations for their well-known silviculture and productivity (FAO, 2001). But, mixed-species plantations with two, three or four species can be more productive and have more advantages in biodiversity, economy and forest health over monocultures (Liua et al., 2018 and Aerts and Honnay, 2011). And this process is said to be *restoration* (Lamb, 1994); where some original species plus where necessary, exotic species are used to reforest of the site.

There are debatable ideas about the establishment of monoculture plantation mainly for biodiversity conservation (Braun et al., 2017). Different literatures reported that the use of exotic species for rehabilitation of degraded land has a benefits for the conservation of biodiversity (Brockerhoff et al., 2008; D'Antonio and Meyerson, 2002); whereas others are suggesting planation of indigenous tree species are used rather than exotic species to maintain functions of forests (Bremer and Farley, 2010; Jha et al., 2013; Lamb, 1994; Putwain and Gillham, 1990; Braun et al., 2017). The following table depicts the disadvantages of planting exotic trees instead of the planation of indigenous tree species to rehabilitate degraded forests and its impacts on the core (production, service and protection) function of forests.

Disadvantages of planting exotic species for rehabilitation	Sources
Some of the species have a tendency of turning out to be invasive, use of repeated rotation in production cause infestation,	Yirdaw et al., 2014; Carandang and Lasco, 1998
Require a lot of fertile land, cause elimination of natural forests for replacement, extensive management	Liu et al, 2018; Wyk et al., 2006; Watt et al., 2009
Exotic species monocultures may change natural habitat conditions typically in ways that do not support biodiversity of native species	Hooper et al., 2002
Exotic species can't recover the original ecosystem and biodiversity	Lamb, 1994
Exotic species are susceptible to increased disease and pest risk	Holmes, 1983

Thus, as the rehabilitation of degraded forests is one of the possible pathways to solve the problem of our environment, restoration works by indigenous species should be encouraged. A good success story of rehabilitation of forest greening implemented by S. Korea, from five significant contribution *i.e.* forest survey and inventory, tree improvement, tree planting and tendering, and forest health management. The country used forest production based on selecting suitable species, preparing seedlings, and plant and mature the trees properly is successful story of forest greening aligned with economic growth (Park et al., 2017).

CONCLUSIONS

In recent years, numerous articles have addressed sustainable management of forests and strategies supporting forests to adapt to climate change. Effects of climate change on the distribution, quantity and quality of forest is clear and many forest ecosystem have been shaped by climate change. Lessons learnt from these facts led to sustainable forest management where control of deforestation, restoration and/or rehabilitation of degraded forest lands are the main components. As restoration, rehabilitation, reforestation and general forest plantations projects are undertaken for a variety of environmental, economic and social objectives, sustainable forest

management component should focus on the restoration of degraded lands by indigenous species. In this case the selection of suitable species for rehabilitation work should get consideration. Because, selecting suitable species is the most important issue for bare land reforestation, degraded secondary forest restoration, and single-species plantation transformation (Wang and Meng, 2018).

REFERENCES

Aerts R and Honnay O (2011). Forest restoration, biodiversity and ecosystem functioning. BMC ecology. 11: 29. doi:10.1186/1472-6785-11-29.

Braun AC, Troeger D, Garcia R, Aguayo RB, and Vogt J, (2017). Assessing the impact of plantation forestry on plant biodiversity: A comparison of sites in Central Chile and Chilean Patagonia. Global ecology conservation 10:159-172.

Bremer LL and Farley KA (2010). Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. Biodivers Conserv. 19:3893–3915. DOI 10.1007/s10531-010-9936-4.

Broadhurst LM, Thomas AJ, Forrest SS, Tom NLG (2016). Maximizing Seed Resources for Restoration in an Uncertain Future. BioScience.73–79. https://doi.org/10.1093/biosci/biv155.

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J, (2008). Plantation forests and biodiversity: oxymoron or opportunity? Biodivers Conserv. 17:925–951.

Burley J (1980). Choice of Tree Species and Possibility of Genetic Improvement for Smallholder and Community Forests. The Commonwealth Forestry Review. 59:3 (181): 311-326. http://www.jstor.org/stable/42607757.

Burton L (2016). Climate change: risks and opportunities in nursery production. Proceedings of the 2016 Annual Meeting of the International Plant Propagators' Society. Pp 5-10. 10.17660/ActaHortic.2017.1174.3

Carandang WM and Lasco RD (1998). Successful Reforestation in the Philippines:Technical Considerations. In: Pulhin F.B., Reyes L.C. and Pecson D.N. (Eds.). Mega Issues in Philippine Forestry: Key Policies and Programs. Forestry development center. ISBN 971-579-007-0: 49-59.

D'Antonio C and Meyerson LA (2002). Exotic plant species as problems and solutions in ecological restoration: a synthesis.Restor. Ecol. 10: 703–713. https://doi.org/10.1046/j.1526-100X.2002.01051.x.

Donald DGM (1979). Nursery and Establishment Techniques as Factors in Productivity of Man-made Forests in Southern Africa, South African Forestry Journal, 109:1. 19-25. DOI: 10.1080/00382167.1979.9630152.

Duryea ML and McClain KM (1984). Altering seedling physiology to improve reforestation success. In: Duryea ML, Brown GN, eds. Seedling physiology and reforestation success. Dordrecht: Martinus Nijhoff /Dr. W. Junk Publishers: 77-114.

Ennosa R, Cottrellb J, Hallc J, and O'Brienc D (2019). Is the introduction of novel exotic forest tree species a rational response to rapid environmental change? – A British perspective. Forest Ecology and Management 432: 718–728. https://doi.org/10.1016/j.foreco.2018.10.018.

FAO (1999). Selecting tree species on the basis of community needs. Community Forestry Field Manual 5. Rome, Italy.

FAO (2001). Global forest resources assessment 2000. FAO Forestry Paper No.140. FAO, Rome, Italy.

Grossnickle SC (2005a). Importance of root growth in overcoming planting stress. New For 30:273–294.

Grossnickle SC (2012). Why seedlings survive: influence of plant attributes. New Forests 43:711–738. DOI 10.1007/s11056-012-9336-6.

Haase D (2018). The role of nursery production in global forest restoration efforts. Book of Abstracts International Conference Reforestation Challenges 20-22 June 2018, Belgrade, Serbia.

Hasenauer H, Gazda A, Konnert M, Lapin K., Mohren GMJ, Spiecker H, van Loo, M., Pötzelsberger E. (Eds.) (2017). Non-Native Tree Species for European Forests: Experiences, Risks and Opportunities. COST Action FP1403 NNEXT Country Reports, Joint Volume. 3rd Edition. University of Natural Resources and Life Sciences, Vienna, Austria. Pp 427.

Hassan R, Scholes R, Ash N, eds. (2005). Ecosystems and Human Well-Being: Currrent State and Trends: Findings of the Condition and Trends Working Group of the Millenium Ecosystem Assessment. Island Press.

Holmes JC, Bergling J, Boss KS, Datcher DM, Henson J, Foster D, Leahy L. and Young D (1983). Sustaining Tropical Forest Resources: Reforestation of Degraded Lands. Background paper #1. U.S. Government Printing Office, Washington, D.C.

Hooper E, Condit R, and Legendre P (2002). Responses of 20 native species to reforestation strategies for abandoned farmland in Panama. Ecological Applications 12:1626–1641.

Hughes CE (1994). Risks of species introductions in tropical forestry. Commonwealth Forestry Review Volume 73 (4): 243- 252.

IPCC (2007). Summary for policy makers. In: Solomon S, Qin D, Manning M (Eds.). The physical science basis. Contribution of working group I to the Fourth Assessment Group of the intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPPC (2017). Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SR2). Background report for the Scoping Meeting, Dublin, Ireland.

Jacobs DF, Oliet JA, Aronson J, Bolte A, Bullock JM, Donoso PJ, Landha¨usser SM, Madsen P, Peng S, Rey-Benayas JM and Weber JC (2015). Restoring forests: What constitutes success in

the twenty-first century? New Forests (2015) 46:601–614. DOI 10.1007/s11056-015-9513-5.

Jha RK, Baral SK, Aryal R and Thapa HB (2013). Restoration of degraded sites with suitable tree species in the Mid-hills of Nepal, BankoJankari 23 (2): 3-13

Keenan RJ (2015). Climate change impacts and adaptation in forest management: a review. Annals of Forest Science, Springer Verlag/EDP Sciences, 72 (2), pp.145-167. Ff10.1007/s13595-014-0446-5ff. ffhal-01284173f.

Keenan RJ (2015). Climate change impacts and adaptation in forest management: a review. Annals of Forest Science 72:145–167. DOI 10.1007/s13595-014-0446-5.

Kest T (2015). What is the size of deforestation in 21st century? Human and nature. Contributoria. Accessed 16/05/2019.

Kobayashi S (2007). An overview of techniques for the rehabilitation of degraded tropical forests and biodiversity conservation. Current Science Vol. 93, No. 11. pp. 1596-1603.

Koslowski TT, Kramer EJ and Pallardy SG (1991). The physial ecology of woody plants, Aademi press, Incude USA.

Krishnan R, Rajwant P, Kalia K, Tewari JC and Roy MM (2014). Plant Nursery Management: Principles and Practices. Central Arid Zone Research Institute, Jodhpur. Pp. 40

Kumar R and Das AJ (2014). Climate Change and its Impact on Land Degradation: Imperative Need to Focus. J Climatol Weather Forecasting 2: 108. doi:10.4172/2332-2594.1000108.

Lamb D (1994). Reforestation of Degraded Tropical Forest Lands in the Asia-Pacific Region. Journal of Tropical Forest Science, 7(1), 1-7. Retrieved from http://www.jstor.org/stable/43581787

Lamb D and Tomlinson M (1994). Forest Rehabilitation in the Asia-Pacific Region: Past Lessons and Present Uncertainties. Journal of Tropical Forest Science, 7(1), 157-170. Retrieved from http://www.jstor.org/stable/43581800

Lavender DP (1984). Plant Physiology and Nursery Environment: Interactions Affecting Seedling Growth. In Duryea, Mary L., and Thomas D. Landis (eds.): Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nilhoff/Dr W. junk Publishers, The Hague/Boston/Lancaster, for Forest Research Laboratory, Oregon State University, Corvallis. 386 p.

Liua CLC, Kuchmaa O, Krutovsky KV (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. Global Ecology and conservation 15 e00419. https://doi.org/10.1016/j.gecco.2018.e00419.

Locatelli B, Catterall CP, Imbach P, Kumar C, Lasco R, Marín-Spiotta E, Mercer B, Powers J S, Schwartz N, Uriarte M (2015). Tropical reforestation and climate change: beyond carbon. Restoration Ecology Vol. 23, No. 4, pp. 337–343.

Löf M, Madsen P, Metslaid M, Witzell J, Jacobs DF (2019). Restoring forests: regeneration and ecosystem function for the future. New Forests (2019) 50:139–151. https://doi.org/10.1007/s11056-019-09713-0.

Lu Y, Ranjitkar S, Harrison RD, Xu J, Ou X, Ma X, and He J (2017). Selection of Native Tree Species for Subtropical Forest Restoration in Southwest China. PloS one, 12(1), e0170418. doi:10.1371/journal.pone.0170418.

Martin ST (2009). Climate Change Impacts: Vegetation. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0021227

Mathers HM, Lowe SB, Scagel C, Tuve DKS and Case LT, (2007). Abiotic Factors Influencing Root Growth of Woody Nursery Plants in Containers. Hort technology, 17(2). Pp 151-162.

McTague JP and Tiius RW (1996). The Effects of Seedling Quality and Forest Site Weather on Field Survival of Ponderosa Pine. Tree planter's notes. Pp 16-23.

Mittal R and Mittal CG (2013). Impact of Population Explosion on Environment. Modern Rohini Education Society (Regd.) | Paper Id: WKB-4028.

Moreira F, Catry F, Lopes T, Bugalho M and Rego F (2009). Comparing survival and size of resprouts and planted trees for post-fire forest restoration in central Portugal, Ecological Engineering, 35, 870-873.

Nyoka BI, Kamanga R, Njoloma J, Jamnadass R, Mng'omba S and Muwanje S (2018). Quality of tree seedlings produced in nurseries in Malawi: an assessment of morphological attributes, Forests, Trees and Livelihoods, 27:2, 103-117. DOI: 10.1080/14728028.2018.1443027.

Park H, Lee JY and Song M (2017). Scientific activities responsible for successful forest greening in Korea, Forest Science and Technology, 13:1, 1-8, DOI: 10.1080/21580103.2016.1278048

Parrotta JA (1992). The role of plantation forests in rehabilitating degraded tropical ecosystems. Agriculture, Ecosystems and Environment, 41 (1992) I 15-133.

Paterson RR, Kumar L, Taylor S, and Lima N (2015). Future climate effects on suitability for growth of oil palms in Malaysia and Indonesia. Scientific reports, 5, 14457. doi:10.1038/srep14457.

Payn T, Carnus JM, Smith PF, Kimberley M, Kollert W, Liu S, Orazio C, Rodriguez L, Silva LN, Wingfield MJ (2015). Changes in planted forests and future global implications. Forest Ecology and Management 352, 57–67.

Pedraza RA and Williams-Linera G (2003). Evaluation of native tree species for the rehabilitation of deforested areas in a Mexican cloud forest. New Forests 26: 83–99, 2003.

Phillips RP, Fei S, Brandt L, Polly D, Zollner P, Saunders MR, Clay K, Iverson L, Widhalm M, and Dukes JS (2018). Indiana's Future Forests: A Report from the Indiana Climate Change Impacts Assessment. Purdue Climate Change Research Center. West Lafayette, Indiana. DOI: 10.5703/1288284316652

Putwain PD and Gillham DA (1990). The significance of the dormant viable seed bank in the restoration of Heathlands. Biological Conservation, 52, 1-16.

Reubens B, Moeremans C, Poesen J, Nyssen J, Tewoldeberhan S, Franzel S, Deckers J, Orwa C, Muys B (2011). Tree species selection for land rehabilitation in Ethiopia: from fragmented knowledge to an integrated multi criteria decision approach. Agroforestry Systems, 82:303–330.

Roy HE, Bacon J, Beckmann B, Harrower CA, Hill MO, Isaac, NJB, Preston, CD, Rathod, B, Rorke, SL, Marchant, JH, Musgrove, AJ, Noble, DG, Sewell, J, Seeley, B, Sweet, N, Adams, L, Bishop, J, Jukes, AR, Walker, KJ, Pearman, DA (2012). Non-Native Species in Great Britain: establishment, detection and reporting to inform effective decision making. FRP - Final Report. Pp 110

Sanderson EW, Jaiteh M, Levy MA, Redford KH, Wannebo AV, Woolner G, (2002). The human footprint and the last of the wild. BioScience 52(10): 891-904.

Sarah P and Zonana M (2015). Livestock redistribute runoff and sediments in semi-arid rangeland areas. Solid Earth6: 433–443. https://doi.org/10.5194/se-6-433-2015.

Schiappacasse I, Nahuelhual L, Vasquez F, Echeverria C (2012). Assessing the benefits and costs of dryland forest restoration in central Chile. Journal of Environmental Management 97: 38–45. https://dx.doi.org/10.1016/j.jenvman.2011.11.007.

Sedjo R and Sohngen B (1998). Impacts of Climate Change on Forests. Internet edition. Resources for the Future. Pp 1-8.

Shimamoto CY, Padial AA, da Rosa CM, Marques MCM (2018). Restoration of ecosystem services in tropical forests: A global meta-analysis. PLoS ONE 13(12): e0208523. https://doi.org/ 10.1371/journal.pone.0208523.

Simula M, El-Lakany H and Tomaselli I (2011). Restoration, rehabilitation, reforestation and plantations. International Tropical Timber Council. Summary Report. La Antigua Guatemala, Guatemala.

Solomon T and Moon H (2018). Expansion of exotic tree species and impacts on management of the indigenous trees; emphasis on eucalyptus species in Wolaita, South Ethiopia - a review. International Journal of Research and Review. 2018; 5(1):15-20.

Thomas E, Jalonen R, Loo J, Boshier D, Gallo L, Cavers S, Bordács S, Smith P, Bozzano M (2014). Genetic considerations in ecosystem restoration using native tree species. Forest Ecology and Management 333 (2014) 66–75.

Uhl C, (1988). Restoration of Degraded Lands in the Amazon Basin. In: Wilson E.O. and Frances M. Peter (Eds.). Biodiversity. Washington (DC): National Academies Press (US); 1988. ISBN-10: 0-309-03783-2ISBN-10: 0-309-03739-5

United Nations (2017). The world population prospects. Department of Economics and Social Affairs. New York.

Wang J and Meng J (2018). Identifying indigenous tree species for land reforestation, forest restoration, and plantation transformation on Hainan Island, China. J. Mt. Sci. 15: 2433. https://doi.org/10.1007/s11629-018-4861-1.

Warren JM, Meinzer FC, Brooks JR and Domec JC (2005). Vertical stratification of soil water storage and release dynamics in Pacific Northwest coniferous forests. Agric. For. Meteorol. 130: 39-58.

Watt MS, Kriticos DJ, Alcaraz S, Brown AV, and Leriche A (2009). The hosts and potential geographic range of Dothistroma needle blight. Forest Ecology and Management 257:1505–1519.

Whittet R, Cottrell J, Cavers S, Pecurul M, Ennos R (2016). Supplying trees in an era of environmental uncertainty: Identifying challenges faced by the forest nursery sector in Great Britain. Land Use Policy 58: 415–426. doi: 10.1016/j.landusepol.2016.07.027.

Williams MI and Dumroese RK (2014). Role of climate change in reforestation and nursery practices. Western Forester. 59(1): 11-13.

Wyk GV, Pepler D, Gebrehiwot K, Aerts R, and Muys B (2006). The potential and risks of using exotics for the rehabilitation of Ethiopian dry land forests. Journal of the Dry lands 1(2): 148-157.

Yirdaw E, Tigabu M, Lemenih M, Negash M, and Teketay D (2014). Rehabilitation of degraded forest and woodland ecosystems in Ethiopia for sustenance of livelihoods and ecosystem services. In: Katila P., Galloway G., de Jong W., Pacheco P., Mery G. (Eds.). Forests under Pressure – Local Responses to Global Issue. IUFRO World Series Volume 32. ISBN 978-3-902762-30-6. pp. 299–313.

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