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Opinion

A Novel Approach to Restoration of Tropical Dry Forest in Hawaii

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Abstract

Hawaiian tropical dry forests are vanishing and there is desperate need to develop new strategies and approaches to save and restore such forests. The foggy weather conditions in the Hawaiian Islands make possible the utilization fog collection nets to increase water input for afforestation in dry areas of the islands. In this paper we proposed a novel approach for dry forest restoration in Hawaii: adopting fog collection technology combined with plantings of both native and non-invasive exotic species. This approach addresses promoting ecosystem function, rather than conserving individual species. Implementation of such an approach requires a philosophy of integrity and innovation, public-private cooperation, and network-based adaptive management.

Introduction

Tropical dry forests comprise nearly half of the world's tropical and subtropical forests [1], crossing large areas of southeastern Africa, eastern Bolivia, central Brazil, the Caribbean, and the Asia Pacific region. The tropical dry forests are the most threatened of the major tropical forest types [2,3]. Due to its convenience for land clearance and suitability for agriculture, much of the tropical dry forests have been burned and cleared to make way for agricultural production and cattle grazing, and now continuously face the greatest anthropogenic disturbances[4]. Hundreds of millions of people depend on dry forests but these valuable ecosystems are rapidly disappearing worldwide.

In Hawaii, although it is probably best known for its tropical rain forests with highly diverse species, the dry forests on the islands are equally valuable in terms of biodiversity and endemism. Ninety percent of the plant species on the islands are indigenous or endemic and 45% of the tree and shrub species are on the Federal Endangered Species List[5]. Hawaiian dry forests once had the highest tree species diversity among all the Hawaiian forest types [6] but over 90% of the original dry forest has been eliminated [7]. Land use change, exotic plant and animal invasion, fire, and climate change (especially increasing temperature) have been attributed to the loss and severe degradation of Hawaiian dry forests [8-10]. According to World Wildlife Foundation (WWF), Hawaiian tropical dry forest is on the Global 200 list, with high priority in ecosystem conservation. Hawaiian tropical dry forests are distributed in the leeward regions of the islands where annual precipitation is typically less than 1250mm, and some places only receive 250mm of annual precipitation. Today, alien grasses, such as California grass and fountain grass, dominate the leeward sides of the Hawaiian Islands, which previously supported dry forests. Reforestation started in the 1920s in response to concerns over loss of freshwater supplied by the watersheds once protected by the native forests, It reached a peak in the late 1930s after a massive harvest of trees dominated in dry forests such as sandalwood *(Santalum paniculatum)* and koa*(Acacia koa)* which had been heavily harvested for over a century [6]. Introduced tree species were utilized in the large-scale reforestation efforts and significantly contribute to Hawaii's alien-species crisis, with many of the tree species used for reforestation becoming problematic invasive[11].

In realizing that the invasive species become the most severe barriers to the restoration of Hawaiian tropical dry forests, substantial effort has been made in eradicating invasive species and planting native plants in various restoration programs during the past several decades. However, with invasive plants and animals were successfully eliminated; native species have not been returned to a desired level. In most cases, due to the high regenerative abilities, fast growth rate and abundant soil seed bank of invasive plants, the seedlings of native species planted in the field will soon be covered or replaced by non-native or invasive species and the restoration sites eventually return to an alien-species dominated forest [12]. For example, in a dry forest restoration program the Kaupulehu Dry Forest Preserve in North Kona on the island of Hawaii, nearly 5,000 native seedlings were planted from 1999-2006 and less than 30% of the pants survived in 2007 [10]. To deal with such a challenge, there is a desperate need for effective strategies and approaches in restoration of tropical dry forest in Hawaii.

Approach

The Hawaiian Islands are situated in the center of the Pacific Ocean, a relatively arid part of the Pacific. The mean annual precipitation in the surrounding ocean of the Hawaiian Islands is only about 750mm, according to "The Vanishing Hawaiian Forest" reported by The Nature Conservancy. However, for example the windward slope of the island of Hawaii can receive as much as 3,500 - 4,000mm of precipitation per year. The significantly increased freshwater on the islands comes from the forested upland capture of water in the form of mist, fog and rain. Foggy weather is very common on Hawaiian Islands. Brauman et al. [13] found that fog water intercepted by plant canopy accounted for at least 12% (the north site) and 27% (the south site) of total water input in the dry forest region on the island of Hawaii. Such a weather phenomenon in Hawaii indicates that using fog collection net to increase water input for plant survival could be a powerful tool for dry forest restoration on Hawaiian Islands.

Numerous experiments since 1950's indicated fog has a considerable potential as a water source and fog interception technology has been greatly developed [14-17]. The one of most important factors determining the feasibility of installation of a fog collector or net is the expected water yield. In Hawaii, fog events are frequent and relatively long duration, and are determined by regional climatic factors such as atmospheric moisture, pressure distribution and ocean surface temperature; this combination makes the fog net application highly feasible. Fog collection effectiveness is closely related to structure and design in size, shape, direction, location, as well as the material used [17]. A large project on Peru's south coast proved the feasibility of fog collectors to provide water for afforestation and restoration of the degraded coastal ecosystems [18]. The successful implementation of the project led to another afforestation project in Atiquipa, which also performed successfully [19]. In Spain, a fog collection network

containing 24 fog collectors in 19 locations over an 800km long expense was established on the Iberian Peninsula in 2003 [20]. Freshwater collected by the network played an important role in the hydrological system and water resource management in this area.

Regarding to the materials used for the fog collection net, the previous fog collection projects used synthetic materials such as nylon and polyethylene [17]. To avoid secondary pollution by using the synthetic materials, polylactic acid (PLA) material, which has been used as sandbag barrier for desert control, can be employed for making fog nets. PLA is eco-friendly, completely biodegradable and highly effective in resisting UV damaging. Besides using fog nets, the proposed novel approach includes using both exotic but non-invasive and native species for outplanting. Many previous restoration projects in Hawaii are too ambitious by only planting native trees or shrubs and hardly achieve their goals. A recently published article on a decade-long forest restoration project in Hawaii suggested that following invasive species removal using both native and non-invasive exotic species in a forest restoration project could be functional [21]. Mauna Kea Reforestation Program planted thousands of seedlings of native plant species in the arid areas of the island of Hawaii and found that survival rate of plants planted at the edge of the patched pine trees (non-native) was much higher than that on the open area. The biggest challenge for survival of the planted seedlings is drought between rainy seasons and the outplants often dry out completely. Many fast-growing non-native plants at the early stage of succession can prevent soil moisture from drying out and save the adjacent native plants. Eventually native trees will replace the non-native plants.

Conclusion

Global climate change and anthropogenic land use alteration are the major threat to tropical dry forest. Restoration of such forests faces multiple challenges such as drought, species invasion, fire and non-adaptive management. Comprehensive restoration projects should be developed to promote ecosystem function, rather than conserving individual species. Efforts to the restoration for tropical dry forest need to focus on the impacts of long-term conservation a landscape scale. To deal with the various challenges on dry forest restoration, enhancing public-private cooperation and establishing forest restoration partnership are particularly important.

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