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DEBATE

Highway Genebank: An Ideation for Plant Genetic Resources Conservation on the Highway Margins

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India is an ecologically and culturally diverse country. Every region of this country has a plethora of woody perennials that have the potential to provide food, fibre, fodder, fuel, nutrition, and livelihood to the local population. Promoting access to this wide diversity of multipurpose trees can extensively address the problem of malnutrition and poverty in rural India. Therefore, these valuable biological resources should be conserved for posterity and promoted vigorously to make them accessible to the common citizen. Conservation of these valuable genetic resources and their germplasm in field genebanks is a common practice followed across the globe. But, every country including India faces severe constraint of land resources to upscale such efforts leading to assemblage of proportionately very less number of germplasm in the field genebanks. A massive highway development programme of nearly 69432 km length is being undertaken in India. These highway projects are being planted with tree species to make them green. With an appropriate policy convergence and coordination with various plantation and livelihood schemes, such plantations can conserve thousands of genetically diverse accessions available in the woody perennial while dispensing other benefits that had been stipulated in the plantation programme of the country. A conservative estimate projects that the express highways alone an accommodate nearly 20 million trees. Additionally, such plantations can serve as a platform for advancement of research on woody perennials for students, academicians, social scientists, conservationists etc.

Key Words: *ex situ* conservation, Field genebank, Genetic diversity, Green Highway Policy, MGNREGA, Roadside plantation

Background

Biological Diversity as the cradle of human survival has now been proven beyond doubt. The irony is, those who are well fed in the world give little thought to the challenges which the current food production system is facing. About 3,00,000 species on the earth are edible but only 200 are consumed in a more regular manner. Commercial diversity of food has increased many folds in the recent decades, but diversity in food grains consumption has become abysmally low. Only three crops i.e. rice, maize, and wheat contribute 60% of the energy in human diet leading to deficiency of many essential minerals and vitamins in the global population. Around two billion people in the world are deficient in one or more micronutrients. In India, around one in each 200 total mortality in 2016 was because of deficiency in micronutrients such as Iron, Zinc, Vitamin A etc. (Gonmei and Toteja, 2018). Forty one percent of pre-schoolers, 24% of school-age children and 28% of adolescents are anaemic. Iron deficiency (low serum ferritin) in pre-schoolers, school going children and adolescents is 32%, 17% and 22%, respectively. Female adolescents has a higher prevalence of iron deficiency (31%). In case of Vitamin A, the deficiency is 18%, 22% and 16 % among pre-school, school-age children and adolescents, respectively. Nearly 19% of pre-school children, 17% of school-age children and 32% of adolescents have zinc deficiency. It is important to note that the children and adolescents in urban areas have a higher prevalence of iron deficiency compared to their rural counterparts (MoHFW, 2019). It is also more pervasive in areas that are most productive in the world such as the Indian states of Punjab, Haryana, and Western Uttar Pradesh. These areas also have higher

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average per capita income than rest of the country. This could be primarily due to the shrinkage of food diversity in the daily platter and non-availability of nutritionally rich fruit trees in the surroundings. Shrinkage in food diversity has become much narrower during the last half a century. Our ancestors probably had much more diverse and nutritionally rich food basket than the present generations. For example some bread like products, prepared from club-rush tubers (*Bolboschoenus glaucus*) and seeds of wild einkorn (*Triticum boeoticum*) (one of the ancestors of today's wheat), were used as a food in South-West Asia 14,400 years ago, much before the Fertile Crescent, where agriculture was believed to have been originated 10,000 years ago (Arranz-Otaegui *et al*., 2018; Voss-Fels *et al*., 2019). Ancient texts from across the world such as Greeks, Romans, Mesoptamian, Indus valley, Chinese, etc. had highlighted use of wild plant species for many nutritional and medicinal uses. Indian civilization, traditionally being a knowledge society, has accumulated a plethora of information compiled in valuable texts like Ayurveda, Siddha, Unani, Sowa Rigpa and other folk medicines. Apart from herbs and shrubs many medicinal trees like *Bahera* (*Terminalia belerica*), *Haridra* (*Terminalia chebula*), *Arjun* (*Terminalia arjuna*), *Neem* (*Azadirachta indica*), *Karanj* (*Pongamia glabra*), *Khirni* (*Manilkara hexandra*), *Junipers, Rhododendrons, Taxus,* etc. are extensively used in a wide range of herbal formulations. Demand for these plant based medicines is increasing both nationally and globally. Total consumption of herbal raw drug in India for the year 2014-15 has been estimated at 5,12,000 MT with a corresponding trade value of INR 55 billion (NMPB, 2020). Fruits are rich source of vitamins, minerals, anti-oxidants and many other secondary metabolites required for human health. Fruits like *Karonda* (*Carissa carandas*), *Ber* (*Ziziphus mauritiana*), *Phalsa* (*Grewia asiatica*), *Jamun* (*Syzygium cuminii*), *Lasoda* (*Cordia myxa*), *Sohiong* (*Prunus nepalesnsis*), *Wood Apple* (*Limonia acidissima*), *Star Fruit* (*Averrhoa carambola*), etc. are rich in vitamins and minerals, but are not utilized to their fullest potential in India. Bioavailability of the vitamins and minerals from these fruits is very high and sustainable as compared to the commercially available allopathic capsules and syrups. For example, one single fruit of *Aonla* can provide as much as 8 times vitamin C required by an adult per day. Leaves of *Moringa oleifera* is rich in protein (29.4% dry weight basis), provides 10 times more vitamin A than carrots, 17 times more calcium than milk, 15 times more potassium than bananas, 25 times more iron than spinach and 7 times more vitamin C than oranges (Rockwood *et al*., 2013; Gopalakrishnan *et al*., 2016). Fruits like *Phalsa* and *Karonda* are very rich in Calcium, Iron and Vitamin C. These fruit trees do not require the best fertile soils and can survive well on the marginal lands without any extra care. One or two such fruits in a day can substantially address the issue of anaemia, enhance immunity, bone development, and many other forms of malnutrition in the growing children of our country. Till few decades ago, plenty of such trees were available in the countryside, on community and waste lands which have depleted drastically due to urbanization, habitat loss, deforestation etc. Tree genetic resources also play an important role in livelihood support system in many rural areas. *Gum, resin* and damar yielding trees like *Kusum* (*Schleichera oliosa*), *Palas* (*Butea frondosa*) (for lac culture), *Sal* (*Shorea robusta*), *Chir pine* (*Pinus roxburghii*), etc are economically important trees supporting the livelihood of populations in the rural India. *Neem,* a wonder tree endemic to India, had been used since time immemorial in many traditional medicines, insect repellent etc. New policy of the Government of India to use neem coated urea in urea fertilizer to increase nitrogen use efficiency has increased the demand for neem oil. *Azadirachtin,* an active compound of neem oil, is the primary ingredient used for insect pest control in organic/natural farming, an emerging farming practice to produce green and safe food. Demand for all these plant derived products will increase with the increase in population, standard of living and awareness about using green products.

Threat to the Biological Diversity and the Need for Conservation

Development, urbanization and rampant consumerism of the 21st century have led to devastation of the valuable treasure of plant genetic resources conserved by the earlier generations. According to the Global Forest Resources Assessment 2020, the global rate of net forest loss in 2010–2020 was 7 million ha per year. Every day the world is losing few hundred species i.e. they are becoming extinct thereby pushing the survival of humanity to the brink. More than 32,000 plant species are threatened with extinction (IUCN, 2020); approximately 20,339 trees have been included in the red list of threatened plants. CITES listings of tree species have surged in recent years; more than 900 tree species are now included in CITES appendices and have their trade regulated

(FAO and UNEP, 2020). Rapid urbanization, mining, construction of mega-hydroelectricity projects, road constructions, railway lines, high tension transmission lines and other such anthropogenic interference are the major contributors to deforestation and habitat loss of many valuable species, landraces and ecotypes. Road construction has contributed significantly in depleting the tree vegetation along the road margins. In one of the impact assessment studies undertaken by the National Highways Authority of India (NHAI), it was reported that widening of about 403 km stretch of highway between Agra and Dhanbad demanded to remove approximately 48419 trees. The species included many valuable tree species such as Shisham (*Dalbergia sissoo*), Teak (*Tectona grandis*), Neem (*Azadirachta indica*), Arjun (*Terminalia arjuna*), Jamun (*Syzygium cuminii*), Mango (*Mangifera indica*) etc. (NHAI document E432 volume 17 www.nbrienvis.nic.in/WriteReadData/CMS/Tree%20Plantation%20Strategy%20%20GTR(1).pdf). The scenario is similar in all other road development projects undertaken in the country during the last 10-15 years. Genes of desirable traits present in these valuable species, their wild relatives and land races have tremendously contributed to the survival and productivity of many commercial cultivars. For example the resistance genes $v_{f,}$ $v_{m,}$ $v_{r,}$ $v_{bj,}$ against apple scab, a serious disease hampering apple production across the world, are found in small fruited apple *Malus floribunda*, *M. micromalus*, *M. pumila* and *M. bacata* Jackii, respectively; resistance source of pine wilt disease for Japanese pine (*Pinus pandorosa*) were reported in *P. thunburghii*, *P. luchuensis* and *P.massonianathe* (Nose and Shiraisi, 2008); *Mmd1* gene, resistant against Melamspora leaf rust in *Populus deltoides,* is found in *P.trichocarpa* (Jorge *et al*., 2005); citrus tristeza resistance gene was identified in the citrus relative *Poncirus trifoliata* (Mestre *et al*., 1997). The entire rice crop of Indonesia was threatened some decades ago by a growth-stunting virus. A gene transferred from *Oryza nivara* from Odisha saved rice crop against the virus. The muskmelon crop in the United States was saved from huge loss by transferring a single gene from the Indian germplasm having resistance to downy mildew. Another gene from the Indian genetic resources provided resistance to greenbug insect in sorghum providing millions of dollars of annual benefit to the American farmers. Dr. William Saunders of Canada used wheat variety Hard Red Calcutta and released new series of wheat later called Marquis A and B which were resistant to rusts. Recently in rice, Sub1A (from FR13A) and PSTOL1 (from Kasalath) are being used globally to save rice from losses due to flooding and improving P use efficiency (Singh *et al*., 2021). The genetic resources not only possess the genes and traits for biotic stress but also genes for abiotic stress and adaptive traits relevant to the changing climatic scenarios. Climate change is now a reality; issues of adaptation of a species to climatic aberrations, ecological shifts are likely to put more challenges on the future availability of these valuable forest resources. In India, altitudinal shift of apple in Himachal Pradesh and Uttarakhand, drying of *Parkia roxburghii* in Manipur and Nagaland are few such examples. New plant types, varieties or species are required to fill this gap. Undoubtedly, these precious wealth of genetic resources or germplasm which *Mother Nature* has bestowed upon us, has ample capacity to provide novel genes, traits, plant types or recombinants to face the aforementioned emerging challenges. The invaluable importance of genetic resources can be realized from the supreme sacrifice made by the scientists of All-Union Institute of Plant Industry, later named as Vavilov Institute of Plant Industry, in Russia, during the siege of Leningrad in the Second World War. Scientist like D.S. Ivanov, a rice specialist, M. Shcheglov, G. Kovalevsky, N. Leontjevsky, A. Malygina, A. Korzun and many others had slowly starved to death because of shortage of food but refused to eat the seeds from any of their collection containers of rice, peas, corn and wheat. They chose torment and death in order to preserve their valuable genebank (Krivchenko, 1991; Loskutov, 1999). Therefore, the available biological diversity must be conserved on priority to secure the existence of both the present and future generations.

Conservation of Genetic Resources – Global and National Efforts

In situ conservation of biological resources is considered to be the most ideal conservation strategy for all the biological diversity as it allows the evolutionary, and inter and intra ecosystem interactions to shape the quality and quantity of the natural variation. Accordingly, many biodiversity rich areas, unique habitats, representative ecosystems, gene sanctuaries, biosphere reserves etc. (collectively called as protected areas), have been established across the globe to conserve the biological diversity including plant genetic resources. There are about 257,817 protected areas (including terrestrial ecosystem, ocean and other water bodies) spread over 245 countries in the world (WDPA, 2021). Aichi Biodiversity

Table 1. Protected Areas established in India (As on December, 2019)

Protected Areas	No.	Total Area (km^2)	Coverage % of Country
National Parks (NPs)	101	40,564.03	1.23
Wildlife Sanctuaries (WLSs)	553	119,756.97	3.64
Conservation Reserves (CRs)	86	3,858.25	0.12
Community Reserves	163	833.34	0.03
Protected Areas (PAs)	903	1,65,012.59	5.02

(Source: http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx)

Target 11 of the Strategic Plan for Biodiversity 2010-2020 had set a target of achieving at least 17 per cent of terrestrial and inland water areas under protected areas and other effective area-based conservation by 2020. In India, a good network of national parks, sanctuaries, biosphere reserves also have been established (Table 1). However, *in situ* conservation of plant genetic resources in these protected areas has certain limitations as many natural habitats are becoming vulnerable to destruction by anthropogenic misuse of the natural resources. An analysis by Lewis *et al.* (2019) reported that about 1.1 million km^2 area (both land and water) is being removed annually from the protected areas between 2006-2018. Therefore, *in situ* conservation efforts are supplemented by *ex situ* conservation measures in specially constructed genebanks having long term storage (LTS) and medium term storage (MTS) facilities, Cryo banks, *in vitro* cultures and DNA banks. Species which are difficult to store (recalcitrant seeds, vegetative propagules like Banana or species having long gestation period) are conserved in field genebanks.

Globally, nearly 5.7 million accessions of plant species and their wild relatives covering 7420 genera and 54305 species are being maintained in the LTS, MTS, field genebanks and cryo facilities of 831 genebanks located in 114 countries (WIEWS, 2021). More than 0.8 million accessions from over 600 genera are being maintained in 11 genebanks of Consultative Group on International Agricultural Research (CGIAR) and World Vegetable Centre. A good number of collections are being conserved *ex situ* in the 3400 botanical gardens located in different parts of the world (Bélanger and Pilling, 2019). A special permafrost facility to accommodate safety duplicates has been established deep inside a mountain on a remote island in the Svalbard archipelago, halfway between mainland Norway and the North Pole. This facility, popularly called as "Svalbard Global Seed Vault", has a capacity to store 4.5 million accessions. At present 1,074,537 samples of many unique crops and their land races have been stored in this facility (https://www.croptrust.org/our-work/svalbard-global-seed-vault).

In India, ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), a national facility for conservation of Plant Genetic Resources, was established in 1976 to undertake exploration, collection, characterization, conservation, import and export of germplasm, phyto-sanitary and quarantine of plant genetic resources in India. Now it is one of the leading plant genetic resources organization in the world and the National Genebank ranks 2nd in the world with respect to plant genetic resources conservation. It has a capacity to conserve about one million germplasm in the form of seeds and is currently conserving about 0.45 million accessions belonging to nearly 2,000 species. In cryo-conservation facilities 11,932 accessions, and 1915 accessions *in vitro* have been conserved (*www.nbpgr.ernet.in*). But many of the forest and horticultural tree species cannot be conserved as seeds in seed genebanks due to recalcitrant/intermediate seed storage behaviour. Unlike annual field crops such as cereals, pulses, and vegetables seeds of tree crops are not easy to multiply because of the sole constraint of gestation period.

Additionally conservation of germplasm in the field genebanks offers a unique advantage of evolutionary continuum, at least to a large extent, as compared to the *ex situ* conservation in the seed banks where the evolutionary process and dynamics of the gene interaction in populations is halted. Therefore, live trees in the field gene banks are the only viable and economically cheaper option to conserve, multiply and expand these valuable perennial genetic resources. Realising the importance of germplasm conservation in field genebanks, ICAR-NBPGR is also conserving a large number of accessions of perennial plants in field genebanks in collaboration with its partner institutions in India. For example more than 700 accessions of mango (*Mangifera indica*) in ICAR-Indian Institute of Horticultural Research, Bengaluru, nearly 800 mango germplasm in ICAR-Central Institute of Subtropical Horticulture, Lucknow; about 170 Neem (*Azadirachta indica*) accessions in ICAR-Central Agroforestry Research Institute, Jhansi; 246 accessions of Jackfruit (*Artocarpus heterophyllus*), 162 accessions of Bael (*Aegle marmelos*) at the regional station, Ranchi of ICAR-NBPGR, more than 1400

accessions of *Morus* species at the Central Sericultural Germplasm Resources Centre, Hossur etc. are being conserved in field genebanks.

But, looking at the enormity of the diversity available in the woody perennials and the variation in the edapho-climatic conditions (hot arid to alpine and cold desert) in India, the number of accession conserved in the field genebanks is meagre. For example the number of accessions in some of the most important woody perennials such as Shisham (*Dalbergia sissoo*), *Prosopis cineraria, Tecomela undulata, Populus ciliata, Grewia optiva, Grewia tenax, Buchalania lazan* conserved in field genebanks is not more than 200 accessions per species. The major constraint is the lack of availability of enough area with the research institutions, and universities to accommodate a decent number of accessions to capture the genetic diversity present in a species across its distributional range. In such a scenario, avenue plantation or the roadside plantation offers a unique opportunity for conservation of woody perennial germplasm while fulfilling the national objective of greening the highways.

Roadside Plantation – An Opportunity for Woody Perennial Germplasm Conservation

***Patronage of public roads and roadside plantation in ancient India*:** India has a long history of patronizing plantations of flourishing trees with large canopies in the road sides. The visionary Indian Kings like Chandra Gupta Maurya, Ashoka the Great, and Sher Shah Suri had extensively planted fruit and shade trees along the roads for travel comfort and food availability to their subjects. The foundation of the present day Grand Trunk road was laid long back in the 3rd Century B.C. when Chandra Gupta Maurya constructed a road called *Uttar patha* (Northen road) extending from Pataliputra (Present day Patna) to Taxila in Pakistan. It was further extended to Khorasn in Afghanistan. Later, it was widened and extended to Bengal by the Mauryan King Ashoka. King Ashoka had also laid a large network of roads connecting many cities in the southern India and planted trees alongside the roads. During the 16th century A.D., Sher Sah Suri, developed a road called 'Sadak-e Azam' from Chitagong (in Bangladesh) to Kabul. The Moghul emperors gave patronage to this road which was then known as *Bad-Sahi-Sadak*. The Moghuls constructed *Kos Minars* at regular intervals to indicate the length of the roads and decentralize the road management (Roy, 2010; Jason, 2011; Jason, 2012). The British made it a motorable road which is now popularly known as the Grand Trunk Road. During the long history of highway development in India, plantation of useful trees on both the sides of the roads had been encouraged. Chandra Gupta Mauyra appointed officials to protect the roads and the plantations. Kautalya's Arthasastra even mentions different punishments for cutting or damaging roadside trees. Ashoka planted thousands of Banyan (*Ficus bengalensis*), Peepal (*F. religiosa*), Mango (*Mangifera indica*) etc. trees along the roads. In this way, he created special mango grooves by planting good quality plantations along the roads. The benefits of Jamun trees (*Syzhigum cumini*) along the Delhi roads, especially around the Lutyen's Delhi has been well recognized (Salbitano *et al*., 2016). These plantations are known as one of the most beautiful avenue plantation having fruit production potential of about 500 tonnes/ year. Besides, it is a very good protected source of high-quality perennial germplasm. Road side plantations and the plantations in the gardens nurtured by the royals in India are in fact some of the oldest assemblage of tree germplasm in the world, though these were not looked through the prism of the modern genetic principles to conserve genetic diversity. Their emphasis on tree plantation and concern for their protection had helped in assembling a great amount tree germplasm along the margins of the roads.

Current Tree Plantation Activities in India

Organized plantations was also undertaken throughout the 20th century during the British rule. Avenue Plantation as an activity of the Forest Department was undertaken in Uttar Pradesh, and a Land management circle was established in 1935 (Saha, 1996). After independence in 1947, major road side plantations were undertaken under Social Forestry Programmes in different states of India which were supported by international agencies like SIDA (Swedish International Development Cooperation Agency), CIDA (Canadian International Development Agency), DANIDA (Danish International Development Agency) etc. However, with the implementation of major road development projects (both National Highways and Rural Roads) during the last two decades, Government of India had developed major plantation schemes for the national highways. The major ones are the plantation activities under Green India Mission, MGNREGA (Mahatma Gandhi Rural Employment Guarantee Act) scheme, Green Highways Policy, 2015, Prime

Minister's Gramin Sadak Yojna (PMGSY, called PM's Rural Road Development Scheme), and Compensatory Afforestation Scheme under Compensatory Afforestation Fund Management and Planning Authority (CAMPA), National Afforestation Program (NAP), National Rural Livelihood Mission, Integrated Watershed Management Program, National Rainfed Area Authority etc. Under the MGNREGA, Roadside plantations on the National Highways, State Highways, PMGSY roads are being undertaken throughout the country to provide wage employment while developing productive assets and arrest roadside degradation, global warming etc. As per para 4(1), 1(v) of schedule 1of MGNREGA Act 2005 "Afforestation and tree plantation is to be carried out in common and forest lands, road margins, canal bunds, tank foreshores and coastal belts duly providing usufruct to the households covered in paragraph 5". Accordingly, advisory and guidelines had been issued by the MGNREGA Division, Ministry of Rural Development, Government of India vide circulation no 11017/17/2008/ NREGA (UN) (Part-II) dated 31st July 2014. Under this programme in the Financial Year 2020-21, nearly 18.69 million trees were planted on the roadsides covering a total road length of 54,130 km (including 544 km of National Highway) which benefited 2.93 million beneficiaries (MGNREGA Plantation Report:2020-21). Under the CAMPA, 4,48,914 ha had been stipulated for plantation under compensatory afforestation with a budgetary release of INR 50.32 billion (Appx. USD 750 million) from 2009-10 to 2013-14. This budget also included area under plantation other than the compensatory afforestation. Total area covered under plantation was 1467579 ha that included 389198 ha under compensatory plantation (http://egreenwatch.nic.in/Portal.aspx). With appropriate convergence, a sizeable work can be undertaken on plantation of woody perennial germplasm on the road margins. India has a huge network of national highways. The total length of National Highway in the country at present is 1,32,499 km. It includes the 5,846 kilometres 4 to 6 lane express ways popularly called as golden quadrilateral. Such massive expressways have given a tremendous boost to the national economic growth. Ministry of Road Transport & Highways and Shipping, Government of India had launched Green Highways (Plantation, Transplantation, Beautification & Maintenance) Policy, 2015 with the aim to promote greening of Highway corridors with participation of the community, farmers, private sector, NGOs, and government institutions. It was planned to keep aside 1% of the total project cost of all highways projects for the highway plantation and its maintenance. This could make available approximately INR 10 billion (Appx. USD 142 million) per year for plantation purpose and had the potential to generate employment opportunities for about 0.5 million people in rural areas. (https://morth.nic.in/green-highway). In the implementation plan, it had been emphasized to plant local species on the highway margins following the recommendations made by Indian Road Congress manual for roadside plantation 2009 (IRC:SP:21-2009). Although in the Indian Road Congress guidelines, use of locally available species has been emphasized, no consideration was given to collect and plant the genetic diversity of a species available in a specific locality. In a conservation plan, the most important aspect is the maintenance of Genetic diversity of a species which is defined as "*the variation or dissimilarity in the genetic makeup of the individuals of a species which is the source of their unique features*". The genetic diversity within a species is not only most essential for the survival of the species itself but also for the nutritional and livelihood security of mankind. This aspect of conservation of genetic diversity often takes a backstage in large scale plantation programmes where efforts are being made to accommodate more number of species in a unit area but not the genetic diversity within an individual species. While taking up such mass plantations, more often than not, the seeds/cuttings from a few selected plants are planted leading to loss of the genetic diversity of the area over a period of time due to developmental activities in the region. Under the Prime Ministers Gramin Sadak Yojna (PMGSY), it has been planned to construct 3,93,000 km new roads and upgrade 3,73,000 km existing roads in the rural areas. In a circulation from National Rural Road Development Agency, Ministry of Rural Development, Government of India in 2016, all the implementing agencies were instructed to undertake planation in the roadsides of these rural roads and develop convergence with the local MGNREGA programmes (https://pmgsy.nic.in/sites / default/files/ circular/ver_tree_plnt.pdf). Looking at the activities on such a huge network of road construction in India, opportunities to utilize the roadside planation for germplasm conservation is immense.

Roadmap for Highway Genebank

India has a designated National Highway of 1,32,499 km out of which the National Highway Authority of

India has taken up the task of developing 69432 km length. (https://nhai.gov.in/#/about-nhai; https://nhai.gov.in/#/). It can be safely assumed that appx 25m average width of land would be available on each side of the Highways. As per the guideline prepared by the NHAI, the 1st row of the plantation should be at least 14 m from the central line of the traffic lane to ensure road and traffic safety of the high speed vehicles (www.morth.nic.in). It means, nearly 10-11 m width would be available for plantation of the trees. The actual area available for germplasm plantation may be slightly less as some area may not be practically available because of road safety requirements like presence of steep curves, difficult terrain, overhanging walls in hill sides, presence of bare rocks etc. We may assume that at least 70% of the area should be available which implies that at least 50,000 ha will be available for tree plantation. In the 1st approximation, this land can accommodate nearly 20 million trees at an average spacing of 5 m × 5 m (spacing for individual tree types will vary). Only a fraction of such a big number will be sufficient to plant germplasm of fruit, fodder, timber, fuel, and fibre trees and conserve most of the genetic diversity present in almost all the important tree species available in the country. For rest of the space (area not covered under germplasm), the native population of the trees may be surveyed in the surrounding region of the track. All the seeds can be bulked, and subsets of the bulks can be used to raise nursery for plantation. In this way the diversity of the area can be conserved on the roadsides.

The National Highways in India passes through three types of lands: Forest land, Non-forest land, and community land in tribal areas covered under the 6th schedule of the constitution. Management of these highway plantations will be different for different types of the lands. In Forest Areas, the landownership is vested on the state forest departments. Joint Forest Management (JFM) approach may be adopted with appropriate convergence with Pradhan Mantri Van Dhan Vikash Yojna (PMVDVY) scheme launched by the government of India. The village forest development centre (Van Vikash Kendras) can be the focal point for devising maintenance and benefit sharing of the produce. In case of Tribal areas covered under the 6th schedule, the village institution can be utilized and the village *Darbars* (village councils) shall maintain and share the benefits as per the tribal laws and costumes. For the other Non-forest land, the guidelines of MGNREGA may be followed where each family near the highway should be allotted the *usufruct* of not more than 200 trees. Safety buffer between the road and the 1st line of tree, and the medians may be planted with grasses and medicinal herbs, shrubs having wild fruits etc. as per the NHAI guidelines. However, efforts should be made to accommodate diverse germplasm from the surrounding localities instead of planting from one or two sources.

A robust information management system is required to monitor issues related to the identity of these trees, their utility, management and protection against theft and loss as they will be the national treasure to safeguard: It is also required for replenishment of the seeds in seed genebank, supply of germplasm to the various end users like universities, students, breeders, state line departments etc. Rescue missions for germplasm recovery in case of road widening or other developmental works also require most precise identification of the accessions in the field. Therefore, all the trees can be geo tagged with very high degree of precision using a differential GPS (Global Positioning System) or any other high precision instrument. Those trees can be barcoded and RFID (Radio Frequency Identification) tags, either semi-passive or passive tags, can be embedded in the trees to store all the information such as passport data, date of plantation etc. about the tree. The passive RFIDs derive their energy from the readers by induction. Therefore, they will not require any power source or battery to become functional and can be theoretically utilized for a very longer duration of time. Such technologies can be modified to suit the needs of the germplasm conservation and management. These tags will help to revisit the trees precisely and record data on the trees. In some important locations or for valuable trees or rare plant materials, active tags having a Lithium ion battery can be used which will continuously transmit the information to a receiver and any disturbance to the trees can be immediately detected by the signal receiving station. ICAR-NBPGR is working on a collaborative programme with ICRAF (International Centre for Research in Agroforestry) to optimize this technology for germplasm conservation.

Unlike annual crops, trees have very long gestation period to enter into flowering and fruiting. Therefore, studying the traits through classical genetics methods like generating segregating materials, recombinant inbred lines, near isogenic lines, repeated selfing etc. are not feasible in the scale of money, time and space. But the modern genomic tools can circumvent many such

steps involved in classical genetics if a great variability of these underutilized but valuable tree species can be grown in a uniform plantation site like the margins of the national highways. This will provide a big field research infrastructure for the students, researchers, academicians to advance their research in woody perennials as most of the research organizations do not have such plantations in their institutions because of severe shortage of land resources.

The fruits and other products from these species will have the potential to serve towards nutritional security of the local population. The model can also be slightly modified to cater the needs of industries such as tourism, traditional food banquets etc. Another dimension can be added to the highway genebank for enhancing ecosystem services. Rainwater harvesting structures may be provided for irrigation to the plantation, and/or ground water recharge by using recharge filters and recharge pit. If implemented, the "Highway Genebank Model" will be a unique system of gene conservation of perennial species in the world where roadside plantation can be used for biodiversity conservation while providing a variety of other ecosystem services.

The plantations will serve as the source of valuable genes which the nation may require to fight against climate change, pest and diseases management, enhancing productivity etc. As an off shoot, it can improve the carbon footprint, reduce malnutrition, improve soil health, hydrology, reduce sound pollution, increase birds and other animals that are natural predators of many insect and pest and many other ecosystem services. It can also serve towards meeting the sustainable developments goals (SDGs indicator 2.5.1), and Nationally Determined Contributions (NDC) as per Paris Protocol (2015), the international commitments to which the Government of India is a signatory. It could be a win-win situation for all the stakeholders i.e. government, general public, plant and tree breeders, ecologist, nature lovers and the malnourished children who would be shouldering the future growth and development of the country.

With some of the trees, medicinal plants like *Tinospora codifolia* (Giloe), *Tylophora indica*, *Withania somnifera* (Aswagandha), *Aloe vera*, *Moringa oleifera* can be cultivated in the interspaces which can also support the local primary healthcare system and the surplus can go as a raw material to the Ayurveda industry.

Policy Convergence

Government of India has many policies, schemes and programmes for afforestation of road margins such as MGNREGA, CAMPA, NAP, Prime Minister Van Dhan Vikash Yojna (PMVDVY), IWMP (Integrated Watershed Management Programme), National Agroforestry Policy 2014, GIM (National Mission on Green India), Mission on Integrated Development of Horticulture (MIDH), National Bamboo Mission (NBM) etc. A convergence of such programmes will not only rationalize allocation and utilization of financial resources more efficiently but also make the output multi-objective. An outline of a possibility plan for policy synchronization and interdepartmental interaction for effective implementation of such a programme is given Fig 1.

Schema of Activities

A list of activities is given below that can be undertaken to implement a model plantation (Fig 2) for highway genebank:

1. The choice of species and planting design will depend on the local site conditions. The entire highway can be divided into segments of 100 km length or any other length suitable to the local conditions. The district flora or regional flora published by the Botanical Survey of India, the State Agricultural University, Central Universities, State Universities, KVKs, State Forest Departments, ICAR institutes dealing with fruit and forest trees etc. around the locality of plantation may be consulted for the choice of species. Local communities through the village councils (Gram Panchayat) must be involved in the process of species selection and diversity collection as they have very rich indigenous knowledge on the local flora and fauna. A PRA (Participatory Rural Appraisal) or RRA (Rapid Rural Appraisal) may be conducted which will be useful to prioritise the species and composition of the plantation. It will ensure higher success of the programme implementation.
2. The area needs to be surveyed with respect to soil type and land configuration. Most of the land on both sides of the highway may either be slopping on the sides, degraded having issues of water stagnation at the bottom of the slope due to excavation activities etc. In such cases, shallow ponds could be made at regular intervals to address the issue of water

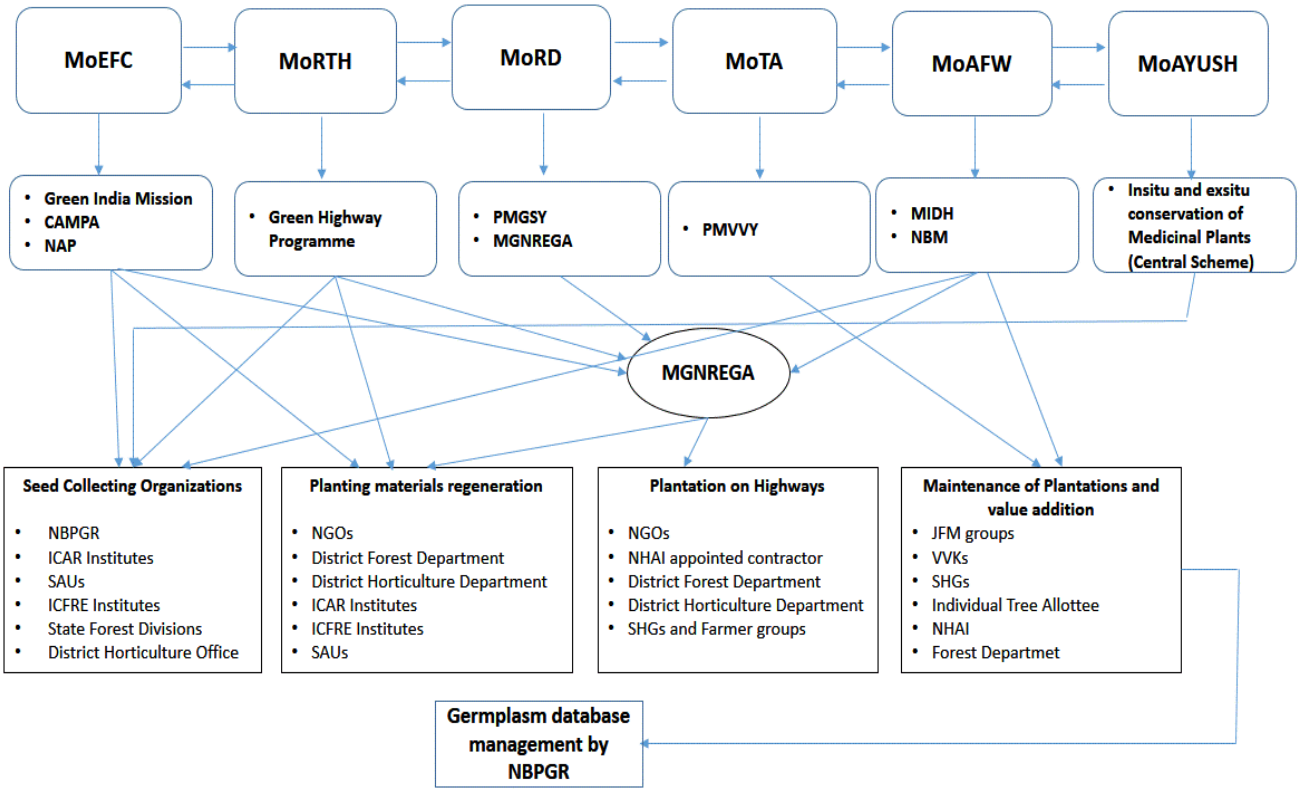
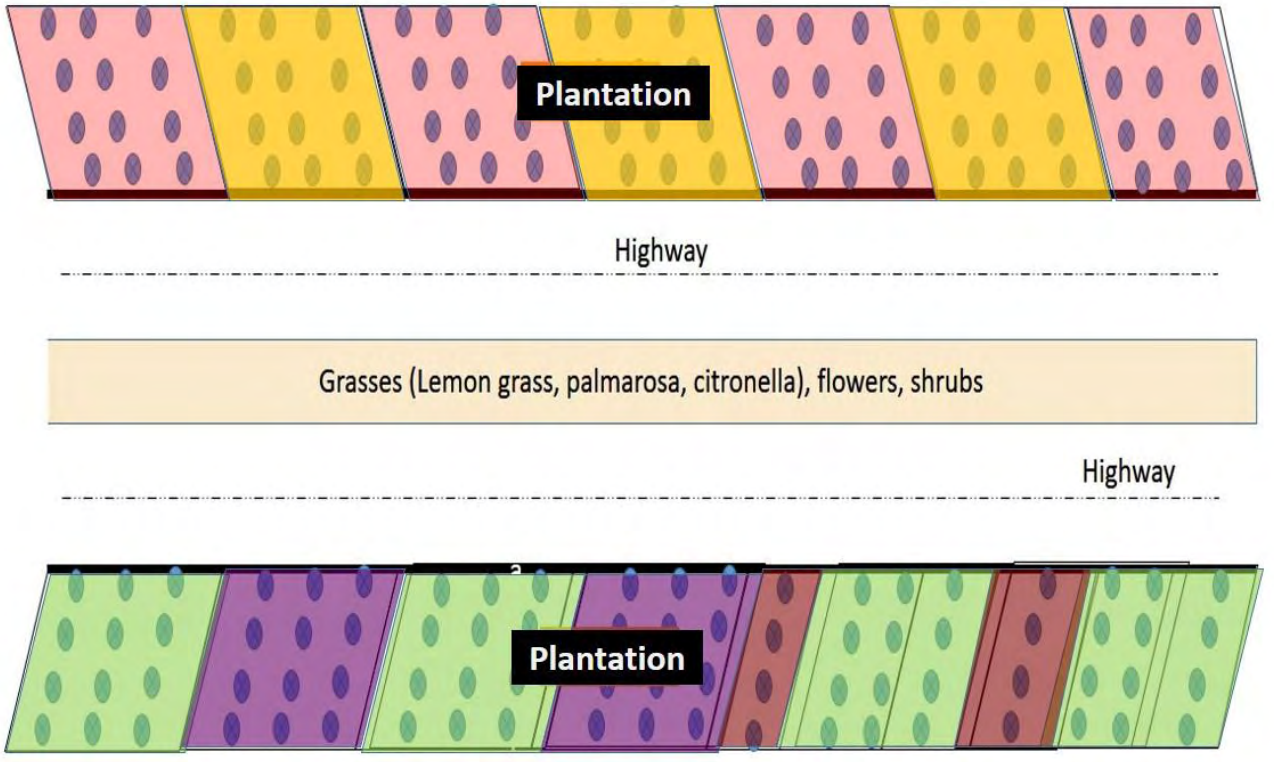


Fig. 1. A proposed plan for convergence of different Ministries and developmental schemes



(Similar colours represent same species but different accession)

Fig. 2. A plan outline of the plantation in the highway margin

ponding near the trees. These harvested water can be utilized for providing life-saving irrigation during rain deficit period.

3. In addition, use of modern tools of geoinformatics, a species suitability mapping of target roads would prove extremely useful. Such technologies will also provide an estimated value of carbon sequestration by such initiatives.
4. The source seeds/cuttings/propagules for plantation of a selected species has to be decided in such a way that it captures maximum genetic variability available in the locality. Expertize available with ICAR-NBPGR and local universities can be utilized for this purpose.
5. Nurseries are to be established near the plantation area. Village nurseries and nurseries established through Women SHGs may be involved to raise seedlings.
6. At least, 40 trees per accession should be planted in order to represent the total variability of the mother plant in the half-sib family/progenies.
7. Digitised records of each tree or population of a particular species will be maintained and seed samples with passport data will be conserved in the National Gene Bank established at NBPGR, New Delhi.
8. The NHAI, local forest department, NGOs, SHGs and individual tree allotees and village institutions may be brought to a common platform to devise the modalities for the management of the plantation.
9. Wherever possible, multitier plantation should be developed keeping view the light requirement of each species in every layer. While doing so the plantation guidelines prepared by the Indian Road Congress 2009 and approved by the National Highway Authority of India may be referred.
10. The highways are provided with channels to drain out the run off generated from the bitumen surface which goes to the small streams and finally to the big rivers; the water is not utilized for any gainful consumptive purpose. These run off, as high as 70-80 % of the rainfall (C value is 0.75-0.95 for road surface, roofs etc) can be harvested for irrigation to the plantation or the ground water may be recharged by using recharge filters and recharge pit.
11. Planting of trees on such lands will require use of advance technologies, so that after care of the trees is minimum and survival rate is higher. For example, use of hydrogels, will reduce the number of irrigations required for the young plantations, especially in the arid/drought prone areas. Similarly, instead of preparing a pit, the plantations can be done using bio-degradable bags, which will reduce the labour/input cost of planting and will enhance the survival percentage of the trees.
12. Incentives and reward schemes may be devised for successful maintenance and management of plantations.
13. Additional models used globally can be reviewed as part of the note as a learning lesson to implement such a valuable and need of the hour model of field preservation of perennial trees genetic resource.

In a nutshell we may exhort *"Save the trees, save the genes and secure the life of the future generations- May the Highways show the light"*.

List of Abbreviations with Translation from Hindi

CAMPA: Compensatory Aforestation Scheme under Compensatory Afforestation Fund Management and Planning Authority

ICAR: Indian Council of Agricultural Research

ICRAF-International Centre for Research on Agroforestry

INR: Indian Rupees

MGNREGA: Mahatma Gandhi National rural Employment Guarantee Act

MIDH: Mission for Integrated Development of Horticulture

MoAFW: Ministry of Agriculture and Farmers Welfare

MoAYUSH: Ministry of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy

MoEFC: Ministry of Forest, Environment and Climate Change

MoRD: Ministry of Rural Development

MoRTH: Ministry of Road Transport and Highways

MoTA: Ministry of Tribal Affairs

NAP: National Aforestation Programme

NBPGR-National Bureau of Plant Genetic Resources

NHAI: National Highway Authority of India

PMGSY: Pradhan Mantri Gramin Sadak Yojna (Prime Minister's Rural Road Scheme)

PMVDVY: Pradhan Mantri Van Dhan Vikash Yojana (Prime Minister's Forest Resources Development Scheme)

VDK: Van Dhan Vikash Kendra (Forest Resources Development Centre)

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