THE SECOND REPORT ON THE STATE OF THE WORLD'S FOREST GENETIC RESOURCES

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This report was prepared as a contribution to the FAO publication, *The Second Report on the State of the World's Forest Genetic Resources*.

Regional networks and international organizations were invited to submit written reports structured around the four strategic priorities of the Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources (FGR)– (1) improving the availability of, and access to, information on FGR; (2) conservation of FGR (*in situ* and *ex situ*); (3) sustainable use, development and management of FGR; and (4) policies, institutions and capacity building.

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CONTRIBUTIONS OF ICRAF TO THE IMPLEMENTATION OF THE GLOBAL PLAN OF ACTION FOR THE CONSERVATION, SUSTAINABLE USE AND DEVELOPMENT OF FOREST GENETIC RESOURCES

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Dr Ms Ramni Jamnadass, Theme Leader, Tree Genetic Resources and Biodiversity, r.jamnadass@cifor-icraf.org; alternate Lars Graudal, l.graudal@cifor-icraf.org

Introduction

1. ICRAF was established in 1978 to promote agroforestry research in developing countries. A Genetic Resources Unit was added in 1990 and the work on tree genetic resources (TGR) further strengthened with the establishment of the ICRAF genebank in 1997, which now hosts the world's largest holdings of agroforestry tree genetic resources. ICRAF is an article 15 Centre under an MoU with FAO on behalf of the governing body of the International Treaty On Plant Genetic Resources For Food And Agriculture (ITPGRFA) with regard to ex situ collections of plant genetic resources for food and agriculture held in trust by ICRAF. ICRAF was part of the CGIAR Genebank Platform 2011-2021. Of the eleven CGIAR Genebanks, the ICRAF Genebank is the only one primarily conserving tree genetic resources. ICRAF led the global research programme "Tree Genetic Resources to bridge production gaps and promote resilience" 2017-2021, which was a flagship project under the CGIAR Research Programme (CRP) on Forests, Trees and Agroforestry (FTA). ICRAF merged in 2019 with CIFOR to become CIFOR-ICRAF while maintaining also separate legal entities. Trees and forest genetic resources, and biodiversity is one of CIFOR-ICRAFs research for impact themes 2020-2030[1].

Priority Area 1: Improving the availability of, and access to, information on forest genetic resources

2. Extensive knowledge resources have been brought together by ICRAF under FTA[2] including the Agroforestry Species Switchboard[3] and the Global Tree Knowledge Platform[4] (GTKP). The Switchboard provides access to more than 50 different webbased information sources on trees and other plants covering more than 172,000 plant species, from across the tropics and more widely. GTKP contains a wide range of tree knowledge products that are relevant to the tropics and globally, including the

[1] https://www.cifor-icraf.org/publications/pdf/CIFOR-ICRAF-Strategy.pdf

[2] Graudal L, Lillesø J-PB, Dawson IK, Abiyu A, Roshetko JM, Nyoka I, Tsobeng A, Kindt R, Pedercini F, Moestrup S, Jalonen R, Thomas E, McMullin S, Carsan S, Hendre P, Kettle C, Li Y and Jamnadass R. 2021. *Tree Seed and Seedling Systems for Resilience and Productivity*. FTA Highlights of a Decade 2011–2021 series. Highlight No. 2. Bogor, Indonesia: The CGIAR Research Program on Forests, Trees and Agroforestry (FTA). DOI: 10.17528/cifor/008212.

[3] Kindt R, John I, Ordonez J, Dawson I, Lillesø J-PB, Muchugi A, Graudal L and Jamnadass R. 2019. *Agroforestry Species Switchboard: A synthesis of information sources to support tree research and development activities*. Version 2.0. Nairobi, Kenya: World Agroforestry (ICRAF).http://www.worldagroforestry.org/products/switchboard.

[4] Kindt R, Dawson I, Graudal L and Jamnadass R. 2021a. *The global tree knowledge platform: A collection of interlinked databases, maps, guidelines, R packages and other decision-support tools to guide planting of the 'right tree in the right place for the right purpose*.' Nairobi, Kenya: World Agroforestry (ICRAF). www.worldagroforestry.org/tree-knowledge.

vegetation map for Africa[5] covering eight countries in East Africa with characteristics of the different vegetation types and information on thousands of useful tree species. GTKP also provide access to maps modelling the effects of climate change, such as the climate change atlases for Central America[6] and Africa[7], which explains how climate change is affecting the distribution of more than 50 Central American trees and more than 100 African trees, respectively, and supports planning for climate-smart seed sourcing. GTKP further holds guidelines and statistical tools that can assist users in performing their own analyses, whether for suitability modelling[8] or genetic changes due to climate change[9] or to find resources useful for applied tree genetic resource management through the Resources for Tree Planing Platform[10] and the recently published databases on Priority Food Tree and Crop Food Composition[11] and Global Useful Native Tree Species[12].

Priority area 2: Conservation of forest genetic resources (*in situ* and *ex situ*)

3. The ICRAF Genebank has a medium-term storage facility in Nairobi which safeguards more than 6,000 seed accessions of 190 species. The Genebank is currently being supported by the Crop Trust but with an acute need of further support after the termination of support from the CGIAR Genebank Platform in 2021. Another 17,000 accessions of more than 681 species are in 49 field genebanks located in 18 countries in Africa, Latin America and Asia. Both the medium-term storage collections and the field genebanks are documented in the Genesys database of the Crop Trust[13]. The ICRAF genebank has over 700 accessions representing 165 tree species held at the Svalbard Global Seed Vault in Norway. The collections are active in contributing to a tree genetic resources management programme supporting not only conservation but all four priority areas of the Global Plan of Action. New collections and field gene banks are being established as part of ICRAF implemented support to ongoing national programmes in Ethiopia and Rwanda with financial support from Norway and the Green Climate Fund, respectively.

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[5] van Breugel P, Kindt R, Lillesø J-PB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F, et al. 2015. *Potential natural vegetation of eastern Africa (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia)*. Version 2.0. Copenhagen, Denmark: Forest & Landscape Denmark, and Nairobi, Kenya: World Agroforestry (ICRAF). https://vegetationmap4africa.org.

[6] de Sousa K, van Zonneveld M, Imbach P, Casanoves F, Kindt R and Ordonez JC. 2017. *Suitability of key Central American agroforestry species under future climates: An atlas*. ICRAF Occasional Paper No. 26. Nairobi, Kenya: World Agroforestry (ICRAF). www.worldagroforestry.org/output/suitability-key-central-american-agroforestry-species-under-future-climates-atlas. [Available in English and Spanish versions].

[7] Kindt R, Abiyu A, Borchardt P, Dawson I, Demissew S, Graudal L, Jamnadass R, Lillesø J-PB, Moestrup S, Pedercini F, et al. 2021. A climate change atlas for Africa of tree species prioritized for forest landscape restoration in Ethiopia. Nairobi, Kenya: World Agroforestry (ICRAF). https://atlas.worldagroforestry.org/.

[8] Kindt R. 2018. Ensemble species distribution modelling with transformed suitability values. *Environmental Modelling & Software* 100:136–145. https://doi.org/10.1016/j.envsoft.2017.11.009.

[9] Kindt R. 2021. Allele Shift: An R package to predict and visualize population-level changes in allele frequencies in response to climate change. PeerJ 9:e11534. https://doi.org/10.7717/peerj.11534.

[10] Schmidt LH, Barsotti D, Moestrup S, Abiyu A, Graudal L, Jamnadass R, Dawson IK, Lillesø J-PB, Kindt R and Robbins AMJ. 2021. The resources for tree planting platform: Delivering high-quality tree-planting material to growers. Copenhagen, Denmark: University of Copenhagen and Nairobi, Kenya: World Agroforestry (ICRAF). https://tree.worldagroforestry.org.

[11] Stadlmayr B, McMullin S, Innocent J, Kindt R and Jamnadass R. 2019. Priority food tree and crop food composition database: Online database. Version 1. Nairobi: World Agroforestry (ICRAF). http://apps.worldagroforestry.org/products/nutrition/index.php/home/reference/

[12] Kindt R, Graudal K, Lillesø J-P et al. 2023 GlobalUsefulNativeTrees, a database of 14,014 tree species, supports synergies between biodiversity recovery and local livelihoods in restoration, 17 March 2023, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-2659652/v1]

[13] Genesys: https://www.genesys-pgr.org/wiews/KEN023. Medim-term storage Seed: https://www.genesys-pgr.org/a/overview/v2KBBe1m4KJ. Field genebanks: https://www.genesys-pgr.org/a/overview/v2WOOMdQPw2.

Priority area 3: Sustainable use, development and management of forest genetic resources

4. As part of FTA, ICRAF has focused on strengthening delivery of planting material for a diversity of tree species. An example is through applying the "Food Tree Portfolio Approach" where suitable food tree species are promoted that, combined with other plant foods, supply required nutrients year-round; the supply of seedlings of the trees is then supported through nursery development and other measures[14]. Up to 2020, such portfolios had been developed for 17 locations in East Africa, and the methods involved have since been expanded to other regions. Rural Resource Centres (RRCs) have been developed to strengthen supply of tree seedlings. RRCs are designed to instruct people in tree propagation, farm management and other skills; and to provide processing facilities, business training and a venue where group associations can meet to market tree products and obtain farm services[15]. A further area of development has been delivering improved orphan tree crops through supporting breeding pathways with the African Orphan Crops Consortium (AOCC)[16] concerned with addressing production gaps for lesser-used food crops including 51 trees that have high potential for addressing nutritional deficiencies in Africa [17]. Specifically, the consortium develops genetic tools for the orphan crops, and sequences representative panels of varieties, genotypes, etc., to explore available genetic diversity[18]. By 2022, genomes of six tree species have been published and a further nine is in progress. To allow for genetic improvement of many species, low input breeding are beeing brought to scale in Ethiopia through the project Provision of Adequate Tree Seed Portfolios (PATSPO)[19], where 30 BSOs of 15 trees prioritized by communities and government in 10 different locations have been established; and more than 200 existing seed sources of mostly indigenous trees have been described and registered.

Priority area 4: Policies, institutions and capacity-building

5. The Food Tree Portfolio Approach, AOCC, RRCs and PATSPO activities led by ICRAF are not only vehicles for delivery but also for capacity building and institutional development. Pilot projects in Kenya, Uganda and Ethiopia that scale up the portfolio approach have reached 6,000 farmers with training and supplied 1,800 smallholder households with a diversity of portfolio trees' seedlings. In Kenya, work with the Kenya Agricultural and Livestock Research Organization has embraced the trials, propagation and distribution of 15 of the prioritized food tree species. AOCC is connected to improved seed delivery

[14] McMullin S, Njogu K, Wekesa B, Gachuiri A, Ngethe E, Stadlmayr B, Jamnadass R and Kehlenbeck K. 2019. Developing fruit tree portfolios that link agriculture more effectively with nutrition and health: A new approach for providing year-round micronutrients to smallholder farmers. *Food Security* 11:1355–1372. https://doi.org/10.1007/s12571-019-00970-7.

[15] Takoutsing B, Tchoundjeu Z, Degrande A, Asaah E and Tsobeng A. 2014. Scaling-up sustainable land management practices through the concept of the rural resource centre: Reconciling farmers' interests with research agendas. *Journal of Agricultural Education and Extension* 20:463–483. https://doi.org/10.1080/1389224X.2014.913984.

[16] Jamnadass R, Mumm RH, Hale I, Hendre P, Muchugi A, Dawson IK, Powell W, Graudal L, Yana-Shapiro H, Simons AJ, et al. 2020. Enhancing African orphan crops with genomics. *Nature Genetics* 52:356–360. https://doi.org/10.1038/s41588-020-0601-x.

[17] AOCC (African Orphan Crops Consortium). 2021. African Orphan Crops Consortium. http://africanorphancrops.org.

[18] Hendre PS, Muthemba S, Kariba R, Muchugi A, Fu Y, Chang Y, Song B, Liu H, Liu M, Liao X, et al. 2019. African Orphan Crops Consortium (AOCC): Status of developing genomic resources for African orphan crops. *Planta* 250:989–1003. https://doi.org/10.1007/s00425-019-03156-9.

[19] ICRAF (World Agroforestry). *Provision of adequate tree seed portfolio in Ethiopia*. http:// www.worldagroforestry.org/project/provision-adequate-tree-seed-portfolio-ethiopia.

through the African Plant Breeding Academy[20], which trains, mentors and empowers Africa's plant breeders to employ state-of-the-art approaches in their breeding work. By the end of 2020, the academy had 114 graduated alumni from 27 African nations. Collectively, these graduates were undertaking breeding work on more than 100 different crops, comprised of a mix of annual and perennial species[16]. AfPBA alumni conceived and helped establish the African Plant Breeders Association (APBA) for the continued professional development of plant breeders on the continent. At its inaugural meeting in Ghana in 2019, there were more than 400 participants. Hundreds of thousands of vegetatively propagated seedlings of a diverse range of fruit trees have been distributed in Central and West Africa through RRCs and their decentralized satellite nurseries, and at the same time producers have been linked to markets[21]. Important positive impacts have been achieved for local communities in terms of income, education, youth and women's empowerment, and health, among other benefits[22]. PATSPO has identified stakeholders in the Ethiopian tree seed sector, promoted collaboration among them, and built their capacity. It has also established breeding seedling orchards (BSOs) to supply quality tree seed; identified and registered other quality natural and planted sources of tree seed; and used low-input "diversity breeding" methods[23,24] to supply appropriate planting material. PATSPO has so far trained more than 2,000 stakeholders in tree seed collection and procurement methods.

6. With the huge global agenda on forest landscape restoration, the importance of quality planting material has emerged as a primary policy challenge, often overlooked as documented e.g. by ICRAF in a pan-tropical review of tree seed supply systems[25] and a survey of the extent to which tree genetic resources are considered in environmental service provision[26]. A policy supported reorientation of stakeholders' roles in tree seed supply systems is considered to be an important element of supporting more effective agroforestry and forest landscape restoration[27] where work to improve tree seed quality should evaluate both supply- and demand-side interventions together, where production and the market

[20] AfPBA (African Plant Breeding Academy). 2021. UC Davis Plant Breeding Academy. University of California. https://pba.ucdavis.edu/PBA_in_Africa.
[21] Asaah EK, Tchoundjeu Z, Leakey RRB, Takousting B, Njong J and Edang I. 2011. Trees, agroforestry and multifunctional agriculture in Cameroon. *International Journal of Agricultural Sustainability* 9:110–119. https://doi.org/10.3763/ijas.2010.0553.
[22] Leakey RRB. 2020. A re-boot of tropical agriculture benefits food production, rural economies, health, social justice and the environment. *Nature Food* (1):260–265. https://doi.org/10.1038/s43016-020-0076-z.
[23] Graudal L, Dawson IK, Hale I, Powell W, Hendre P and Jamnadass R. 2022. 'Systems approach' plant breeding illustrated by trees. *Trends in Plant Science*. https://doi.org/10.1016/j.tplants.2021.09.009.
[24] Hendre, P.S.; Graudal, L.; Kindt, R.; Hale, I.; Powell, W.; Jamnadass, R.; Thomson, L.; Dawson, I.K. 2022, Operationalizing an innovative systems approach for breeding agroforestry trees. CIFOR-ICRAF infobrief No 378 https://doi.org/10.17528/cifor/008758
[25] Nyoka BI, Roshetko J, Jamnadass R, Muriuki J, Kalinganire A, Lillesø J-P B, Beedy T and Cornelius J. 2015b. Tree seed and seedling supply systems: A review of the Asia, Africa and Latin America models. Small-scale Forestry 14:171–191. https://doi.org/10.1007/s11842-014-9280-8.
[26] Roshetko JM, Dawson IK, Urquiola J, Lasco RD, Leimona B, Weber JC, Bozzano M, Lillesø J-PB, Graudal L and Jamnadass R. 2018. To what extent are genetic resources considered in environmental service provision? A case study based on trees and carbon sequestration. Climate and Development 10:755–768. https://doi.org/10.1080/17565529.2017.1334620.
[27] Lillesø J-PB, Harwood C, Derero A, Graudal L, Roshetko JM, Kindt R, Moestrup S, Omondi WO, Holtne N, Mbora A, et al. 2018. Why institutional environments for agroforestry seed systems matter. Development Policy Review 36: O89-O112. https://doi.org/10.1111/dpr.12233.

are seen as two parts of a single, extended and integrated value chain[28] and where climate change is adequately factored in by using climate appropriate portfolios of tree diversity[29].

Concluding remarks

7. National programmes are currently being strengthened through collaboration with ICRAF in Ethiopia with support from Norway (the Norwegian Forest and Climate Initiative) to PATSPO[19], in Rwanda with support from GCF to TREPA[30], and in Burkina Faso with support from GCF[31]. A programme covering five African countries (Ethiopia, Rwanda, Burkina Faso, Kenya and Uganda) with support from the International Climate Initiative (IKI) of Germany is expected to start in 2023. From a practical rather than research perspective, the primary challenge for the coming years will be to scale up the experience already gained in tree seed systems to the world's increasing forest landscape restoration commitments and to its broader tree planting initiatives, particularly through on-the-ground examples of appropriate tree seed system development and policymaker engagement. Such upscaling will provide enormous benefits in terms of climate change mitigation and adaptation, in the restoration of landscapes and conservation of biodiversity, and in the provision of healthy foods and other tree products that support livelihoods. Scaling up will involve further engagement with major global initiatives such as the Bonn Challenge (2021), the UN Decade on Ecosystem Restoration 2021–2030 (UN 2021), and the Global Plan of Action (GPA) for the Conservation, Sustainable Use and Development of Forest Genetic Resources (FAO 2014).

Annexes

Relevant publications and other material is embedded in the text above as footnotes.

[28] Lillesø J-PB, Dawson IK, Graudal L and Jamnadass R. 2021. Quality seed for tree planting: Supporting more effective agroforestry and forest landscape restoration by learning from crop Integrated Seed System Development. ICRAF Policy Brief No. 54. Nairobi, Kenya: World Agroforestry (ICRAF). https://www.worldagroforestry.org/publication/quality-seed-tree-plantingsupporting-more-effective-agroforestry-and-forest-landscape.

[29] Kindt R, Graudal L, Jamnadass R, Pedercini F, McMullin S, Hendre PS, Carsan S, Moestrup S, Abiyu A, Lillesø J-PB, DawsonIK 2023: Operationalizing Climate Appropriate Portfolios of Tree Diversity. 8pp. CIFOR-ICRAF Infobrief No. 383. DOI: https://doi.org/10.17528/cifor-icraf/008850.

[30] https://www.greenclimate.fund/project/fp167

[31] https://www.greenclimate.fund/document/strengthening-sectoral-expertise-and-strategic-framework-support-implementation-climate