

REVIEW

Three Decades of Safeguarding and Promoting Use of Agricultural Biodiversity: Changing Global Perspectives, Paradigm Shifts and Implications

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Abstract

In this study, we explore the global shifts in research priorities and strategies with respect to Plant Genetic Resources (PGR) over a period of nearly 3 decades and also look at changes in donor strategies over the same period, with specific reference to Japanese support to PGR work. We conducted a quantitative text analysis based on reports published by Bioversity International, a leader in PGR issues, and looked at changes in the frequency of appearance of certain terms and words over a 22-year period (1998-2020), divided into six phases. Results show that over the period, Bioversity International's focus transitioned from an emphasis on collection of genetic resources and conservation in genebanks to conservation through sustainable use across generations. This evolved further to "food" -centered approaches. More recently, the emphasis is shifting to "food system" approaches with emphasis on the linkages between agriculture, environment and nutrition. The priority issues of the organization at the different phases are presented. Over the same period, Japanese government investment strategies have shifted from supporting PGR collection work to building capacity of researchers (in both source countries and Japan) and creating more benefits from PGR including nutrition, health and economic benefits to local societies who are the keepers of the PGR. The involvement of Japanese researchers, including the main author, in the various research activities characteristic of the different phases of the transition is presented. In the current global shift towards food systems approaches where the linkage of agriculture, nutrition, and the environment is emphasized, and the involvement of the private sector encouraged, partnerships with resource rich counters will be considered important in PGR activities in the future.

Discipline: Biotechnology

Additional key words: conservation, Japan's assistance, plant genetic resources

Introduction

The Bioversity International (formerly known as International Plant Genetic Resource Institute: IPGRI), was established in 1974 as the International Board for Plant Genetic Resources (IBPGR) under the Food and Agriculture Organization of the UN (FAO). Its first mission was to coordinate an international plant genetic resources programme through organizing collecting missions as well as building and expanding genebanks at national, regional and international levels. The focus of the organization has over the years expanded beyond the emergency conservation of crop genetic resources

in genebanks to include promoting research on how to conserve agrobiodiversity through the sustainable use of genetic resources and harnessing genetic diversity to achieve global benefits. Working with cross-sectoral research collaborators, listening to their advice, and adapting international Plant Genetic Resources (PGR) research to global needs, the organization's research focus and strategies have changed significantly over the last 50 years (CTA 1992).

In 1991, IBPGR changed its name to IPGRI. In 1994, IPGRI began as an independent operation as a member of CGIAR (formerly the Consultative Group of International Agricultural Research) and, at the request of CGIAR,

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IPGRI took over the governance and administration of the International Network for the Improvement of Banana and Plantain (INIBAP). The priority activities were to collect, conserve and use the enormous diversity of plant genetic resources. It collaborated with the national programs to undertake PGR activities at national and regional level and supported several projects in different regions on different PGR activities. In 2006, IPGRI and INIBAP became a single organization and subsequently changed their operating name to Bioversity International. The new name reflected an expanded vision of its role in the area of agricultural and forest biodiversity and research-for-development activities. In 2018, Bioversity International and the International Center for Tropical Agriculture (CIAT) joined forces to create an Alliance, building on their complementary mandates and long collaboration, to respond to today's global challenges of poverty, malnutrition, climate change, land degradation, and biodiversity loss (Table 1) (Bioversity International 2019).

The shifting alliances, mandates, strategies and priorities in the global agricultural research arena over these few decades occurred with the full understanding, participation or influence of the donor community. Japan, a partner of CGIAR and a key player in these early PGR activities was interested in obtaining genetic resources for crop improvement purposes. Changing global focus and priorities in CGIAR and in our case Bioversity International, also meant a concomitant review of Japan's strategic partnership. Other global shifts, included the adoption in 2010, in Nagoya, Japan, of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity. The Protocol changed the way providers and users of genetic resources transacted by providing a strong basis for greater transparency for both and specific obligations to support compliance with domestic legislation or regulatory requirements of the Party providing genetic resources and contractual obligations reflected in mutually agreed terms (Convention on Biological Diversity 2011). In effect, conventional collection became less attractive

as obtaining and using genetic resources obligated parties involved to discuss and agree on benefits (Convention on Biological Diversity 2008).

The purpose of this paper is to visualize these trends including shifts in institutional vision, missions and activities. This has been done through quantitative text analysis based on reports published over a 22-year period (1998-2020) by Bioversity International, a leading international research organization in PGR activities. At the same time, the paper presents the shift in donor thinking with respect to genetic resources with particular reference to Japan's involvement in PGR and support to the institute, giving specific case studies of Bioversity International projects which have benefited from Japan's support. The shifts in priorities have created new opportunities for partnerships with respect to PGR. Some of the prospects for partnership with Japan are described at the end.

Method

In order to visualize the trends, dynamism and transition of activities of Bioversity International, KH Coder (Higuchi 2016, 2017) was used for the quantitative analysis of text mining. Significant words and compound words extracted from the data in different time series and their frequency of appearance and correlation were analyzed. A total of 877 Bioversity International's news features and annual report articles published over 22 years (between 1998 and 2020) were used for the analysis (Fig. 1). Word cluster, TermExtract function was used to extract 111 collocation words and specify these words for forced extraction (TAG words). A total of 17,254 words were extracted and used for the analysis. These consisted of 5,620 nouns, 5,356 proper nouns, 108 TAG words, 3,569 adjectives, 551 adverbs and 1,475 verbs. The number of times the extracted words appeared in the text was counted, and the frequency of appearance identified. In order to identify the trends of the keywords over the period, a set of six phases, each with a five-year span were identified and the number of appearances of extracted

Table 1. Institutional highlights from 1974 to today

1974	Started a major effort to collect genetic resources as the International Board for Plant Genetic Resources (IBPGR)
1991	Became the International Plant genetic Resources institute (IPGRI)
1994	Merged with the International Network for the Improvement of Banana and Plantain (INIBAP)
2004	Served as technical support in negotiations for the International Treaty of Plant Genetic Resources for Food and Agriculture
2006	INIBAP and IPGRI begin working under the name Bioversity International
2012	Became a co-organizer of the international collaboration 'Landscapes for People, Food and Nature' led by Ecoagriculture Partners
2018	Bioversity International and the International Center for Tropical Agriculture (CIAT) signed a Memorandum of Understanding to create an Alliance
2020	Operationalized the new institutional framework, the Alliance of Bioversity and CIAT

Source: Bioversity International 2019. Partly modified by author

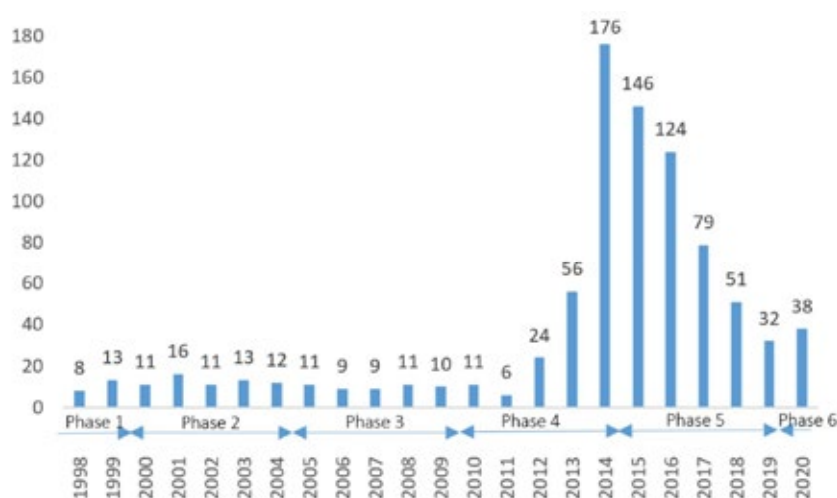


Fig.1. Number of news feature articles used for analysis over the years

Source: Author's own

words for each phase calculated. The text data before 1998 was not included in this analysis due to lack of PDF text documents of annual reports (they are in jpeg image hence the characters could not be recognized by the computer).

Results

For the entire list of extracted words, “farmer” was the most frequently used at 2,584 times, followed by “Bioversity International” (2,113), “food” (1,922), “crop” (1,715) and “research” (1,463). A network analysis of co-occurrence of these key words clarified the links between these keywords. “crop”, “Bioversity International”, “food” and “farmer” are detected as words that play the role of mediating centrality. “Bioversity International” closely linked to words such as “development”, “research”, “food security”, “climate change”, “partnerships” and “projects”. Bioversity International” is also linked to the group of words such as “food”, “agriculture”, “nutrition”, “diet” and “health” on the one hand, and “crop” on the other, and beyond link to the core group of “farmer” (Fig.2).

Table 2 shows a list of the top 30 words with the highest number of extractions in each phase. Based on the extracted words, a multi-correspondence analysis divided into six phases was performed in order to visualize what words were used for the articles according to the chronological phases and form the word groups. The words with similar appearance patterns are categorized in a two-dimensional plot (Fig. 3). Blue circles indicate “words” and red squares indicate “each phase”. The size of bubbles reflects the frequency of word appearance and number of articles in each phase. The words placed near the center (0,0), are the words that appear on average in each document, and are used throughout the entire period. On the other hand, words that deviate from the center indicate

that their appearance is symbolic to that particular phase. Moreover, word groups, which plotted close to each other, represent the similarity of the activities in each phase. The horizontal axis (component 1) represents the object of the activity, giving the interpretation that the further to the right, the more the genetic resources are targeted, and conversely, the further to the left, the more the people are targeted. In contrast, the vertical axis (component 2) is not as clear as the horizontal axis, but it represents the objectives of the activity, and it is considered that the higher the axis, the more the conservation oriented activities are highlighted, and conversely, the lower the axis, the more the development oriented activities are highlighted.

Looking at both Table 2, Table 3 and Fig 2, in Phase 1 (-1999), Including the organization name “IPGRI” and its constituent words “genetic resources”, and the synonyms “plant genetic resources (PGR)”, “genetic diversity”, “germplasm”, as well as “material”, “information”, “network”, have a high frequency of appearance, and it can be seen that they are the symbolic words of the institution in this period. “genetic resources”, and the synonyms are literally present in even in later phases (Table 3).

Bioversity International had since its inception in 1974, laid as its priority to collect, conserve and use the enormous diversity of plant genetic resources to create more productive, resilient and sustainable harvests. It collaborated with the national programs to undertake PGR activities at national and regional levels. It supported several PGR projects in different regions, established genetic resources programmes (genebanks) where they did not exist and funded the training of scientists and technicians throughout the world in PGR activities - from germplasm collections (more than 550 collecting missions, 200,000 samples of crops in 136 countries),

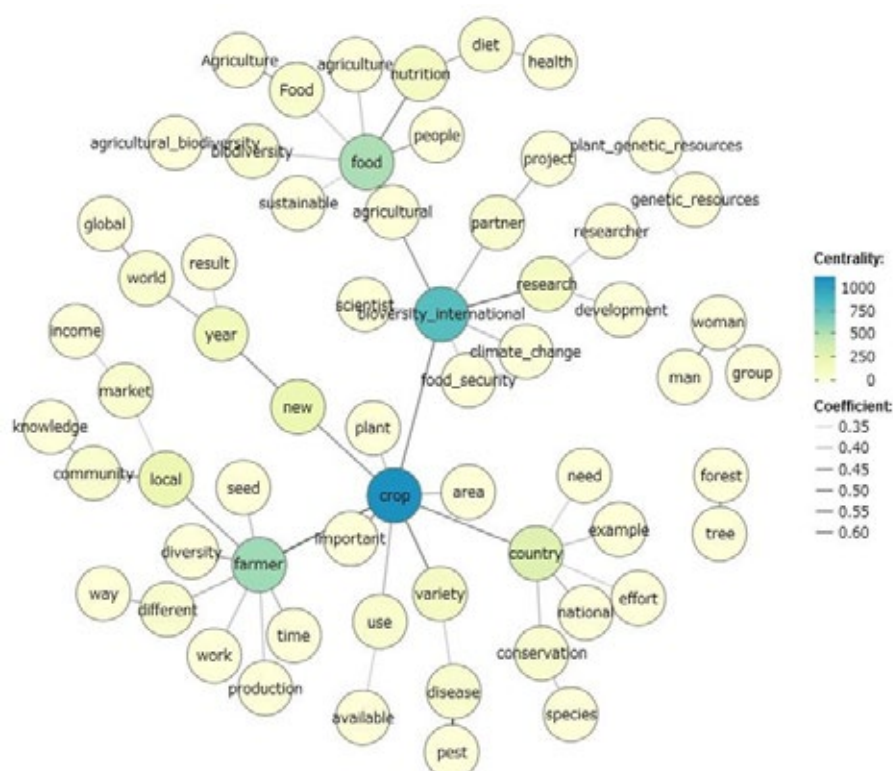


Fig. 2. Co-Occurrence network of the major key words (centrality betweenness)

The strength of co-occurrence was calculated using the Jaccard coefficient, and the network was drawn using the top 250 strongest co-occurrences. Darker lines for strong edges and draw the minimum spanning tree functions of KH Coder were used.

Source: Author's own

Table 2. List of top 30 words extracted in each phase

No	Phase 1 (1999)	TF	Phase 2 (2000-2004)	TF	Phase 3 (2005-2009)	TF	Phase 4 (2010-2014)	TF	Phase 5 (2015-2019)	TF	Phase 6 (2020-)	TF
1	IPGRI	186	farmer	318	farmer	326	biodiversity_international	724	biodiversity_international	1366	food	144
2	genetic_resources	108	project	269	project	276	farmer	583	farmer	1247	farmer	125
3	crop	103	IPGRI	253	variety	210	food	542	food	1085	crop	97
4	country	101	variety	224	Biodiversity	187	crop	440	crop	774	seed	96
5	develop	87	country	185	crop	169	research	409	research	763	country	85
6	species	80	make	182	diversity	160	forest	358	seed	741	use	73
7	information	79	diversity	164	make	142	use	338	community	688	Alliance	72
8	network	76	crop	162	banana	138	community	312	variety	673	bean	72
9	research	76	use	157	grow	134	woman	308	use	663	global	71
10	use	70	seed	146	seed	134	country	298	banana	591	research	68
11	farmer	62	genetic_resources	143	use	131	year	293	woman	574	woman	66
12	plant_genetic_resources	57	develop	139	people	100	seed	291	country	527	variety	60
13	diversity	54	improve	139	help	99	agricultural_biodiversity	286	biodiversity	520	include	57
14	material	49	species	139	important	96	climate_change	285	local	510	increase	57
15	provide	49	conservation	138	develop	94	variety	277	improve	509	food_systems	56
16	make	48	people	121	plant	91	improve	271	new	503	world	56
17	conservation	47	plant	116	country	90	diversity	269	nutrition	479	forest	55
18	project	47	use	116	work	90	tree	268	climate_change	477	project	55
19	training	47	work	114	new	89	conservation	265	species	477	grow	54
20	use	47	information	113	disease	87	world	250	year	472	improve	54
21	variety	47	new	111	area	83	different	246	include	466	make	54
22	genetic_diversity	46	grow	107	improve	82	biodiversity	245	work	463	production	54
23	gemplasm	46	year	106	need	82	global	244	people	450	community	51
24	increase	46	help	101	study	79	work	240	tree	450	develop	51
25	national	46	banana	100	information	78	people	239	make	449	new	50
26	collection	43	research	98	local	78	provide	232	diversity	439	time	50
27	conserve	43	different	97	species	78	important	230	project	432	agricultural	49
28	work	43	food	96	community	77	species	226	global	410	cassava	49
29	fruit	42	partner	95	food	76	develop	224	different	393	researcher	49
30	help	42	local	93	conservation	74	nutrition	220	diet	392	need	48

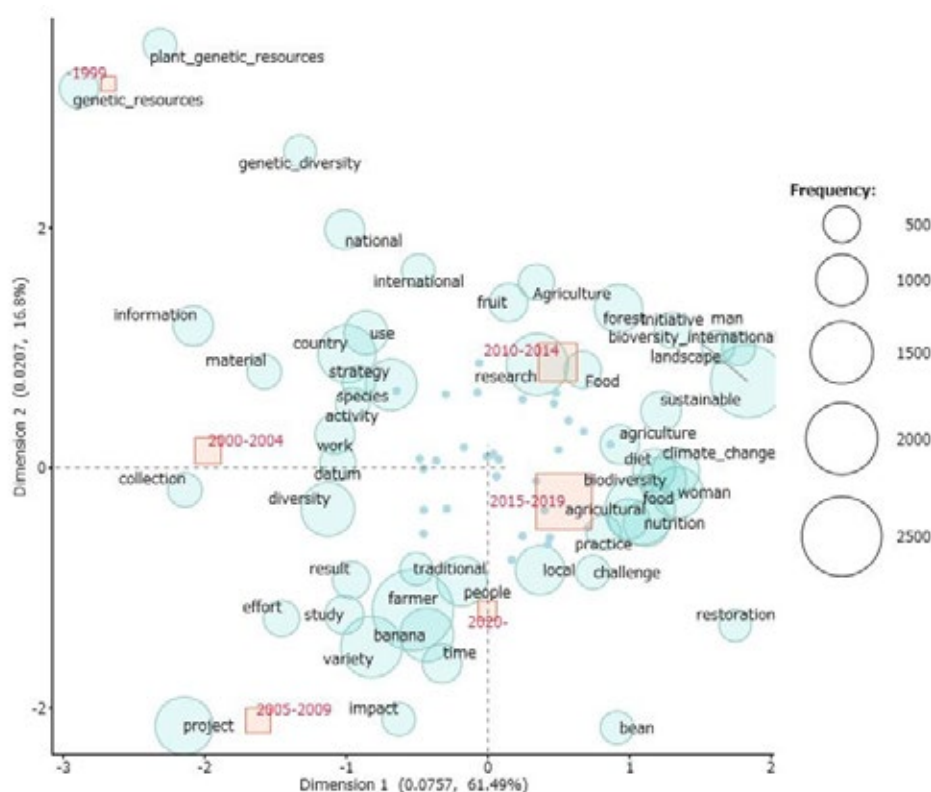
TF: Total frequency.

Source: Author's own

Table 3. Frequency of appearance of symbolic words and synonyms in each phase

CODE (synonyms)	Phase 1 (-1999)		Phase 2 (2000-2004)		Phase 3 (2005-2009)		Phase 4 (2010-2014)		Phase 5 (2015-2019)		Phase 6 (2020-)		Total		chi-square
	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate	Frequency	Rate	
*genetic resources (plant_genetic_resources or genetic_resources or germplasm or genetic_diversity)	20	0.95	57	0.90	34	0.68	146	0.53	242	0.56	20	0.53	519	0.59	44.6**
*collection (material or collection or genebank)	17	0.81	44	0.70	28	0.56	93	0.34	156	0.36	17	0.45	355	0.40	50.2**
*farmer (farmer or people)	13	0.62	54	0.86	43	0.86	181	0.66	325	0.75	33	0.87	649	0.74	21.8**
*landscape (landscape or climate_change)	0	0.00	10	0.16	11	0.22	142	0.52	225	0.52	20	0.53	408	0.47	63.4**
*nutrition (nutrition or diet)	5	0.24	8	0.13	21	0.42	95	0.35	200	0.46	19	0.50	348	0.40	33.8**
woman (woman or women or gender)	4	0.19	9	0.14	15	0.30	73	0.27	144	0.33	9	0.24	254	0.29	12.80
*Food system (food_systems)	0	0.00	0	0.00	2	0.04	26	0.10	82	0.19	12	0.32	122	0.14	41.2**
*Japan (Japan or Japanese scientists)	4	0.19	3	0.05	7	0.14	6	0.02	4	0.01	1	0.03	25	0.03	20.4**
No of Documents	21		63		50		273		432		38		877		
Rate: >0.80															
Rate: >0.50															
Rate: <0.50															

Source: Author's own

**Fig. 3. Time series of word group appearance**

Filtered top 80 words by chi-square value and used top 50 distinctive words in the labels. The word 'IPGRI' is located outside the upper left scale zone and it is not plotted in the diagram.

Source: Author's own

seed physiology to computerized databases to manage genebank materials.

In the following Phase 2 (2000-2004), “farmer” and “project” were confirmed the most frequently used at 318 and 269 times respectively. In this phase Bioversity International reviewed its new institutional vision, changing its focus from “genetic resources” to “farmer” and putting “people”, especially poor people in developing countries, at the center of its agenda. It was a transition from emergency conservation of the “genetic resources”, to use “genetic resources”, “information” and “material” for development. The word “farmer” continued to be a

major word up to phase 6, remaining the symbolic word of the institute for more than 20 years.

In phase 3 (2005-2009), Bioversity International and INIBAP became a single organization and subsequently changed the operating name to Bioversity International in 2006. Initially, the name often shortened to “Bioversity”. The new name reflected an expanded vision of its role in the area of agricultural and forest biodiversity and research-for-development activities. There was a growing realization that, over and above its role as a source of raw material for improved varieties, agricultural biodiversity has a direct part to play in reducing hunger and poverty, in

improving health, especially of women and children, and in promoting sustainability.

The frequently used words in Phase 4 (2010-2015) and phase 5 (2015-2019) are similar. Some of the symbolic words identified for both phases, “food”, “agricultural biodiversity”, “sustainable”, “women”, “climate change”, “landscape”, “nutrition”, are plotted at the right hand side of the diagram. These words show prominence as a precursor to the symbolic words that might follow later phases. This indicates the institutional contributions were assessed in development oriented outcomes, strategic focus being to diversify diets, production systems, seeds and planting material, and to safeguard biodiversity. In this phase, CGIAR embarked on a change process to improve the engagement between all stakeholders in international agricultural research for development—donors, researchers and beneficiaries—and to refocus the efforts of the centers on major global development challenges such as Sustainable Development Goals (SDGs). CGIAR Research Programs (CRPs), multi-center and multi-partner initiatives were established to build on three core principles: impact on CGIAR’s four system-level objectives; making the most of the centers’ strengths; and strong and effective partnerships. A key objective was to integrate the work of the centers and their partners, avoiding fragmentation and duplication of effort. In addition, Bioversity International’s News articles were shifted from being published in Annual reports (hard copy) to Internet web pages after 2013, and the number of articles took a significant leap forward. There was a temporary decrease in the number of articles in the run-up to the alliance with CIAT, which started in 2018, and an increase in the number of articles after the establishment of the operation system of Alliance in 2020, with the completion of a new unified internet site (Fig. 1).

In January 2020 (Phase 6), the new institutional framework, the Alliance of Bioversity International and CIAT was operationalized and a new strategy (2020–2025) established for Accelerated Change (Alliance of Bioversity International and CIAT 2019: Food system solutions at the nexus of agriculture, environment, and nutrition with the aim to deliver research-based solutions that harness agricultural biodiversity and sustainably transform food systems to improve people’s lives in a climate crisis). The Alliance’s first unified strategy, capitalizes on the combined strengths of the two organizations – including genebanks, use and conservation of agricultural and tree biodiversity, climate-smart agriculture, nutrition, digital agriculture, crop improvement, and participatory research approaches – to develop solutions to current crises, through a clear focus - working at the nexus of agriculture, environment, and nutrition. The keywords also echoed the

new institutional roles in the area of “beans”, “cassava” and “food systems” to improve people’s lives to respond to the global challenges of poverty, malnutrition, climate change, land degradation and biodiversity loss, call for solutions, innovation and stronger partnerships that can deliver higher impacts.

Shifts in the engagement of development partners (donors): the case of Japan

Within the same period, we also notice that the thinking and the level of engagement of development partners shifted significantly, often reflecting the changes taking place in CGIAR. In this paper, we have taken Japan as a representative development partner, firstly because it has been a key ally since the beginning of CGIAR and secondly its activities are quite familiar to the authors. A total of 25 news articles involved Japan and/or Japanese researchers, making about 3% of the total number of news articles analyzed. Phase 1 had 4 articles or 19% of the total number articles in that phase, the highest percentage of all the phases. This was followed by Phase 3, with 7 articles forming 14% of all the articles in Phase 3 (Table 3).

During the 1st phase (-1999), the Japanese government’s support for Bioversity International accounted for about 10-20% of the institute’s total income. Japan’s financial contribution peaked in 1999 (\$2.3 million). This was at the beginning of Japan’s new Genebank Program (1985), and the Japanese government strengthened the collection and introduction of genetic resources from abroad at a pace of about 10,000 accessions each year. Japan contributed to several international genetic resources exploration missions to India, Italy, Thailand, Iran, Pakistan, Myanmar and Central Asian countries, through Bioversity International’s coordination. Japan provided support for research exchange in introduction of genetic resources and the use for breeding. In addition, Japan contributed significantly to the decoding of the rice genome, and also to the infrastructure development for long-term storage technology of the genetic resources such as banana, sweet potato, taro, coconut and other tropical fruit trees and potatoes in liquid nitrogen under ultra-low temperature (-196°C). Based on the results, new crop varieties e.g. resistant to drought and pests have been developed using various genomic resources supported by Bioversity International. Furthermore, Japan contributed to initiatives such as genetic resource evaluation and breeding of forest resources such as bamboo and rattan, sharing of genetic resource information, and the development of processed products. Japan too supported international cooperation in genetic resources, including the development of information management systems such as the System-wide Information Network on Genetic

Resources of CGIAR (SINGER), International Network on Bamboo and Rattan (INBAR) as well as human resource development to promote access, exchange, and use of information related to PGR (FAO 2009). Bioversity International activities were important for Japan. As a government priority at the time, securing genetic resources for future crop breeding would only be possible through international cooperation and partnerships.

Japanese contribution decreased however during Phase 2 (2000–2004), as Japan's total official development assistance (ODA) contribution declined. The contribution fell to less than 1% of the total institutional budget (18 million US\$) in 2007. We notice that Japan changed its support focus to human and intellectual development and promoting collaborative research through active Japanese researcher participation. This new approach has seen many Japanese researchers partner with local researchers in various initiatives including conservation, documentation, training and capacity building and public awareness. For example, through Japanese support, the author Dr. Yasuyuki Morimoto from May 2000 to the present has been providing support to local scientists, developing research tools, and empowering local communities in local genetic resources management and use to improve livelihoods. His PGR research activities have covered various fields including PGR use and indigenous knowledge systems, conservation through use, value-adding and nutrition and health in the Sub-Saharan Africa (SSA) region. The new Japanese approach has seen Japanese researchers contribute to some successful initiatives e.g. African leafy vegetable research and promotion, revitalizing the use of traditional foods to improve nutrition and livelihoods, the development of the SATOYAMA resilience toolkit (Bergamini et al. 2014), participatory vulnerability assessments toolkit (Ulrichs et al. 2015),

Agrobiodiversity Diet Diagnosis Interventions Toolkit: ADD-IT (Induli et al. 2018) and documentation activities to reconfirm the value of underutilized crop genetic resources; traditional foodways (Bioversity International 2013). The African leafy vegetables project work has been presented at least six (6) times in different articles (Table 4). The Japan's investment in these activities has not only had a development impact on local communities (Table 5) but also contribution to the institute's mission, and which later became the foundation of Bioversity International's global dietary diversity and nutrition programme.

Discussion

Over the last three decades, there has been a paradigm shift from conservation of genetic material in genebanks only to conservation through use as lack of use can itself be a cause for genetic loss. This is more so for underutilized species and varieties which form the bulk of the food resources. Facilitating increased access and use of agrobiodiversity/ food diversity for food security, local cuisines and livelihoods including nutrition and health can help in conserving such genetic resources. More recently, the focus has shifted to food system which also incorporate food culture including local cuisines, livelihoods and the environment. Although the news articles used in this study are only a small portion of the reports and papers Bioversity International has published over the past 22 years, the results of the text mining analysis, nevertheless show that there has been an evolution of the organization's priorities and that of CGIAR as a whole. This supports the observation that PGR activities around the world have diversified over the past quarter of a century, from an emphasis on genetic resources conservation in genebanks to conservation through sustainable use across generations.

Table 4. A list of the news articles that Japan and Japanese researchers involved

No of articles	Key topics
6	African leafy vegetable research and use promotion
4	Partnership with Satoyama Initiative, developing SATOYAMA resilience toolkit
3	Revitalizing use of traditional foods to boost nutrition and income including Pop-cereal project
2	International Network on Bamboo and Rattan (INBR)
2	Diverse diets fight malnutrition, Better data for better nutrition, Agrobiodiversity Diet Diagnosis Interventions Toolkit (ADD-IT) project
1	System-wide Genetic Resources Programme (SGRP)
1	Organic banana production
1	Japan's Capacity Building Programs
1	COP10 Nagoya
1	In memory of Mr Mitsuaki Tanabe (banana sculptures)
1	Participatory vulnerability assessments toolkit
1	Cooperation work with Nissin Foods Ltd
1	Cassava research in Asia

Source: Author's own

Appendix 1. A case study and major achievements of African leafy vegetables (ALVs) project in Kenya (1995-2006)

Bioversity International strategy on poverty reduction through stimulating use of biodiversity and underutilized species gave ALVs a unique opportunity to make a long lasting social impact in the area of food and nutrition security, especially for the millions of vulnerable and resource-poor households in Africa. The initial phase (1995-1999) of the project looked to conserve agricultural biodiversity by documenting, identifying, and genetically analyzing ALVs. The study identified issues hindering their cultivation, conservation and marketing, about 210 species were recorded in Kenya alone, yet only about 10 of these found their way to markets, usually back-street markets frequented by a small number of regular customers.

A subsequent phase (2001-2006) sought to enhance the genetic material of priority ALVs, 24 species which considered high potential for markets such as Amaranth (*Amaranthus* sp.), Pumpkin (*Cucurbita* sp.), Cowpea (*Vigna* sp.), and Jew's mallow (*Corchorus* sp.).

The promotion took the form of cooking demonstrations, street and media campaigns, field days, posters and leaflets providing recipes and nutritional benefits of the food. Alongside promotion work, the project gathered germplasm some of which was improved at the World Vegetable Centre facilities in Arusha. Improved seeds were distributed to farmers and seed companies. Farmers around Nairobi city got agronomic support and were also linked to formal markets, and disseminate information on nutrition benefits of local vegetables to target communities.

The activity improved the consumption of ALVs, resulting in their enhanced presence in both formal and informal markets as well as the increased capacity of smallholder farmers to respond to market demand. The project contributed that sales of ALVs at the major supermarkets in Nairobi rocketed significantly upward, increasing from 31 tons/month to 400 tons/month (1,100%) over a period of three years from 2001. This new development at the major supermarkets in Nairobi created a new cultural trend, with people in urban cities in Kenya reconsidering the value of traditional foods. Production and marketing slowly moved from city suburbs into rural areas. Increased demand resulted in production chains that generate income and job opportunities in rural villages and that enhance dietary diversification and health in urban areas. Attitudes had changed from that of stigma to pride and the once neglected traditional vegetables were a centre of interest for development workers and researchers.

The work has practically demonstrated how, through increased awareness by a multi-disciplinary research and development, neglected and underutilised local vegetables can again become part of the local diet, contributing to the nutrition, health and income of women, particularly in peri-urban areas. An impact assessment conducted in 2006 and 2007 positively attributed increased activity to the work of the consortium (Gotor & Irungu 2010).

In 2008, a Kenyan young scientist, Ms Miriam Imbumi received an award on "Improvement of nutritional value, health and income by African leafy vegetables" from the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) in Japan, representing a series of achievement on this activity (Research Council, Agriculture, Forestry and Fisheries 2008).



Fig. 4. African leafy vegetable promotion in Uchumi supermarket in Nairobi

Source: P.Maundu

Now a further shift is envisioned, from “food” centered approaches to “food systems” with emphasis on the linkages between agriculture, environment and nutrition (Table 2, Table 3 and Fig. 3). A wide range of diversified research themes such as nutrition/health, environment, economics, society, and development have become mainstream, in addition to the conventional approaches in assessing genetic materials for breeding. In order to adapt to these changes and to achieve their missions, the Alliance’s report of 2020 states in the following four strategic objectives (Alliance of Bioversity International and CIAT 2019);

1. People consume diverse, nutritious, and safe foods.
2. People participate in and benefit from inclusive, innovative, and diversified agri-food markets.
3. People sustainably manage farms, forests, and landscapes that are productive and resilient to climate change.
4. Communities and institutions sustainably use and safeguard agricultural biodiversity.

However, the differences in concentration ratio in particular words observed in each phase in Table 3 was not sufficient to pull out the contribution to the dynamics of the Bioversity International strategy and the relationship to donor support. This is due to the fact that the articles used in the analysis related only to Bioversity International activities that had been implemented within an overall direction of development. The CGIAR centers, including Bioversity International, are accelerating their integration into a single CGIAR institution (One CGIAR) to consolidate their activities and personnel around the world as an international center of agricultural research and to move toward efficient operations. This fits well with the food systems approach.

Donor support

We have seen that the priority areas for Bioversity International and to some extent that of CGIAR have shifted in the last few decades. At the same time donor interests and the way of engaging the research centers have also been changing as exemplified by Japan in this paper. While some of the institutional changes have in most cases been made in partnership with the donors, some of the major shifts have been initiated by the donors or been as a response to donor demands. We have also seen that Japan, a major partner of CGIAR has over the years changed its strategies with respect to PGR, from a donor supporting genetic resource collection and conservation to a partner providing capacity development and support through human resources in new areas especially genetic resource use for improved livelihoods and development. Although

the amount of Japan’s financial support to CGIAR and Bioversity International has decreased since 2000, the continued support through Japanese researchers has led to a number of concrete results including research and promotion of African leafy vegetables, revitalizing the use of traditional foods for improved nutrition and livelihoods, and other new innovative research approaches involving research and technology development to improve farmers’ attitudes toward cultivation, use and consumption of under-utilized genetic resources. Japan’s support such as hosting interns in research projects, collaborating with development organizations in partnership with the private sector, and other development agencies has also contributed significantly to regional PGR activities and development achievements in these fields (Table 5, 6). There is a gradual but growing movement to raise awareness of underutilized crop genetic resources among developing country governments and policy makers. The research evidence generated is more than ever needed to call for a significant change in paradigm and in food systems: as a matter of fact agrobiodiversity is key if we want farmers to be resilient, to provide the nutrients people need for a healthy life and to provide livelihood benefits and bring people out of poverty.

The importance of working with diverse partners

The international situation regarding genetic resources is challenging the status quo and raising questions as to whether we will deliver the current genetic resources to the next generations as a resource for humanity. On the other hand, it is expected that restrictions on access to genetic resources will continue to be tightened for activities aimed solely at collecting them. In future, we need to conduct our activities in a direction that is in line with these international trends. In other words, we need to take an approach that maximizes the use of local genetic resources, participates in development activities that are beneficial to the regions and countries that possess genetic resources, and collaborate with resource-rich countries in the search for added value, including new uses for them. To achieve this, it is necessary for researchers and various relevant stakeholders in the society to work as a team to promote practices that solve problems while staying close to local farmers. Strengthening our food system efforts will not be limited to plants and crops, but also to animals, insects, and microorganisms, and will help maximize their use, not only in terms of production but also in commercialization including processing, distribution, and sales (Alliance of Bioversity International and CIAT 2020). Active involvement through establishing strategic partnerships with resource-rich countries, including

Table 5. Summary of Japanese internship themes, hosted country office, and year of the study

	Research themes	Study country	Year
1	Community Plant Genetic Resources Use and Conservation Needs Assessment in Kenya	Kenya	2006-2007
2	Characterizing biological diversity of local banana landraces and diversity management system in the Buganda region.	Uganda	2007
3	Use and Conservation of Indigenous Fruit Tree Diversity for Improved Livelihoods in the Mijikenda community in Coast Province.	Kenya	2007
4	The cropping strategy in Kitui, Kenya -a case study at several smallholder farms-	Kenya	2008
5	Assessment of local seed flows and agrobiodiversity use in Kitui, Kenya.	Kenya	2008
6	Community-based assessment of local farmer's variety recognition and seed flow networks in Kitui, Kenya	Kenya	2009
7	Community-based assessment for Agrobiodiversity Use and Conservation in Kenya	Kenya	2009
8	Biological and Ethnobotanical Characteristics of Nipa Palm (<i>Nypa fruticans</i> Wurmb.)	Malaysia	2009-2011
9	Farmers' Variety Perception and Selection Criteria in Kitui, Kenya	Kenya	2010
10	Assessment of farmers' agrobiodiversity management in Kenya: The cropping strategy in Kitui district in eastern Kenya	Kenya	2010
11	Understanding how Kitui farmers of Eastern Kenya mobilize agro-biodiversity, social networks and other assets as strategies for coping with adverse effects of climate and social changes	Kenya	2011
12	Assessing farmers' traditional vegetable seeds adoption and dissemination behaviour in Kitui, Kenya	Kenya	2011
13	Assessing local strategies of managing agro-biodiversity under different agro-ecological conditions, Kitui, Kenya	Kenya	2011
14	Examining cultural and religious practices related to seed exchange and management among farmers of Eastern Kenya	Kenya	2012
15	Assessing relationships in agro-biodiversity, socio-economic, ecological and market data sets generated during the Dietary Diversity (DD) project in Kitui, Kenya	Kenya	2012
16	Evaluation of the nutritional content of local Kenyan food items and dishes.	Japan	2020-2023

Source: Authors

technical support, training of young researchers and demonstrating the potential benefits of local resources are considered important for PGR research in the future. In light of these trends, the Japanese government needs to strengthen its support system and human resource development to enable partners in each field to work together to tackle complex global issues such as genetic resources conservation, food and nutrition, and the environment, while exercising their respective strengths

in the fields of agriculture, economics, environment, science and technology, and diplomacy. CGIAR has the potential as an international organization to build strong partnerships with regional research institutions, private companies, government agencies, and universities to propose, demonstrate, and scale up locally relevant solutions to global challenges, not only with researchers, but also with students and the younger generation in the regions.

Table 6. Examples of activities where Bioversity has collaborated with Japanese companies, universities, research institutes, and public institutions

Japanese partners	Research themes / year	Details and achievements
United Nations Educational, Scientific and Cultural Organization (UNESCO), with the financial support of Japanese government	Documenting traditional foodways of Kenyan communities:- (2009-2011)	Developed a community participatory tool for documenting local food systems, whole range of local foods of a community and its seasonality, how food is sourced in the landscape, prepared and consumed and the roles of the household and community members involved. The tool encourages the participation of youth in the community to document foodways using modern communication techniques – e.g. a digital camera, social media and simple notebooks. The wisdom and knowledge of the ancestors on genetic resources is an important resource both for local people and also resource-rich countries as it facilitates advanced research and development of new products. The developed tool has been tried in different activities in Kenya, Ethiopia, Uganda, Ghana, Burkina Faso, and confirmed effective for initiating community based research in the region and improving awareness of the diversity of food resources and the importance of conservation in the surveyed community (Bioversity International 2013).
Suzu City, Ishikawa Prefecture, Japan, Institute for Global Environmental Strategies (IGES), United Nations University Institute for the Advanced Study (UNU-IAS)	Toolkit for Indicators of resilience in socio-ecological production landscapes and seascapes: SEPLS (2012-2019)	In order to build resilient systems that can mitigate and manage risks, while securing healthy ecosystems and the well-being of local communities, the team and others developed a new toolkit for resilience indicators in socio-ecological production landscapes and seascapes. The toolkit is useful for NGOs, development agencies, and policy-makers working on biodiversity conservation and sustainable development with local communities, and for the communities themselves, to understand and then increase their capacity to endure in the face of social, economic, and environmental pressures and shocks, to improve their environmental and economic conditions. The toolkit was released in a Satoyama-initiative side event on IUCN World Parks Congress 2014 in Sydney, Australia and has been implemented in more than 10 different countries in Africa, Asia, and South America. Suzu city in Ishikawa Prefecture, Japan adopted the tool for evaluating the level of awareness on resilience of the community people. A case study in Tanzania revealed that a high level of awareness of the diversity of rural landscapes and local agricultural products is highly correlated with the tendency to reduce environmental resilience and risk (Bergamini et al, 2014).
Mitsubishi Chemical Corporation, United Nations Development Program (UNDP)	Demonstrating an inclusive business model through water purification and agricultural promotion projects (2012-2013)	The project demonstrated an inclusive business model for a sand-filtered water purification system that aims to increase water use efficiency while generating incomes for local communities. The water purification system provided an opportunity to sell purified water to local residents and the activated charcoal used to purify the water was also used as a soil conditioner for vegetable cultivation through drip irrigation. Bioversity provided local vegetable seeds and nutritional education for the local community. The project raised local awareness of health (water) and nutrition (traditional vegetables) among local residents and contributed to the economic independence of the community (Mitsubishi Chemical 2015).
Nissin Foods LTD	Instant noodles for Africa (2014)	Bioversity scientist proposed test making of instant noodles from local gluten free cereals such as Sorghum (<i>Sorghum bicolor</i>), and Pearl millet (<i>Pennisetum glaucum</i>). Nissin adopted the idea, started a new venture for producing instant noodles containing Sorghum flour, developed new package designs, business strategies and marketed widely in the East African region (Bioversity International 2014)
Wago Co., Ltd, IMG consultant, JICA	Strengthening the Group Management Capacity of Small-scale Horticultural Farmers in Kenya (2014-2015)	Involved as a team member of the baseline survey of the project. The assessment results led to the Kenyan business of Wagoen LTD, which focuses on local production of sweet tomatoes, strawberries and other high value-added fruit and vegetable products (Wago 2015).
University of Nagasaki	Kaken research fund B (2014-2016)	This study aimed to examine the impact of people's perceptions and expectations of education on future economic development. The study was implemented in two countries, Kenya and India. Bioversity scientists participated in the research activities in Kitui County, Kenya, and provided a research platform, including field work coordination.

IEDA Confectionary LTD (a Japanese private company), Japan Association for International Collaboration of Agriculture and Forestry (JAICAF)	Feasibility Survey on Local Production for Local Consumption (Chisan-Chisho). Activity and Extension in Africa (Pop-cereal intervention project). (2016-2018)	In order to address the challenges of food security and health by enhancing consumption of affordable, locally available yet nutritious snacks, Bioversity scientists developed new markets for traditional grains and seeds in Africa, through ‘popcorn’ made from sorghum, finger millet, rice, bambara nuts, soybean and a host of other ‘unfashionable’ grains. With technical support from Japanese partners, DK engineering co. LTD, fabricated a prototype pop cereal machine using only locally available materials and experimental production and sales of pop cereal snacks were initiated by the local communities and entrepreneurs. The intervention resulted in 1) DK Engineering Ltd established mass production technologies of pressure pop cereal machines, 2) several cases where local community groups and individual entrepreneurs subsequently purchased the machine with their own funds and initiated their local business based on puffing via their own motivation and fund-raising efforts. Three local communities in Embu, Migori and Bomet counties initiated a business production to explore the puffing properties of a number of local grains, showing innovations through flavoring with a diversity of local fruits, vegetables and aromatic plants healthy local snacks for both local and urban people and especially children. This technology demonstrated a new source of income for rural groups and has the potential of spurring rural economies where these minor crops are grown. It added new economic value for local food resources used as snack, providing employment to the youth and bringing extra income to women farmers (Langat 2020).
United Nations Industrial Development Organization (UNIDO) with the financial support of Japanese government	Creation of a new industry that will provide a new source of income for women’s organizations in Beretweyne, Hilaan State, Somalia. (2017-2018)	The experience of the pop cereal business in Kenya led to the establishment of another community-based activity in Somalia. The production and sale of popping cereal products increased the average income of the target women groups by 20% (Ministry of Foreign Affairs of Japan (2020)
Tokyo University of Agriculture, Axis Co., Ltd. (IT company)	A new integrated food consumption assessment tool for better decision making in nutrition interventions project (2017-2022)	Developing a new information and communication technology (ICT) system tool (Agrobiodiversity and Diet Diagnosis for Interventions Toolkit: ADD-IT for assessing local diets using mobile and tablet devices. The project has the following specific objectives. To develop and perfect the ADD-IT system tool through field tests. To assess and monitor local food systems, food availability and dietary patterns/ shifts including food choices and consumption behaviour. To understand the nature and causes of dietary challenges. To provide local food-based balanced dietary options. (Induli 2018)
Tokyo University of Agriculture, Jomo Kenyatta University of Agriculture and Technology and Sokoine Agricultural University	Problem-solving education program for improving nutrition in Africa (2021-2025)	Facilitating support for establishing a new international inter-university student exchanges program in the field of nutritional analysis and food functional research of underutilized food diversity in Africa.
Nanzan University, Mekelle University, Ieda Confectionery Co., Ltd.	The Nanzan university challenge program (a private industry-University Collaboration initiative) (in planning 2020)	The experience of the pop cereal business in Kenya led to the establishment of another community-based development project in Northern Ethiopia. The Nanzan university established a new inter-university partnership program with Mekelle University in Ethiopia to facilitate pop cereal industries using locally available underutilised cereals and grains, and students to raise awareness (Kisala 2020).
RIKEN, The University of Tokyo, Totori University	Creating a new insect food industry to solve the global protein crisis (In preparation 2020)	In response to the global protein crisis, this team is planning to conduct basic research in Japan and Kenya to establish “new insect diets” as a new protein source that can be sustainably and stably supplied. The results of this research will lead to establishing a “new insect diet” as a new industry in Africa. A joint team in Japan and Kenya is coordinating the application process for this initiative.

Source: Authors

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