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Knowledge Paper

Strategic response to invasive and migratory pests – the emerging global pandemic

December 2020

#GTBharat
SHAPING A VIBRANT INDIA

Message from Hon'ble Minister

Shri Parshottam Rupala

Hon'ble Minister of State for
Agriculture and Farmers Welfare

परशोत्तम रूपाला
PARSHOTTAM RUPALA

सत्यमेव जयते

राज्य मंत्री
कृषि एवं किसान कल्याण
भारत सरकार
Minister of State For
Agriculture & Farmers Welfare
Government of India
D.O. No.....MOS(A&FW)/VIP/2019-20/
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Message

It was my pleasure to inaugurate the Webinar on **Invasive & Migratory Pest Management: Challenges and Way forward** organized by ASSOCHAM on 23rd November 2020.

Agriculture is the backbone of the Indian economy and any losses occurring to the pre-harvest and post-harvest crops need to be minimized. In 2017, farmers in India incurred heavy losses in crop yields in at least nine major agricultural states due to an erratic monsoon and subsequent pest attacks. The annual and currently ongoing locust infestation over Africa, West Asia and South Asia is perhaps the most dangerous of all insect infestations. There are also rising instances of 'alien' plant and pest species invading India and damaging crops. In the past 15 years, India has had at least 10 major invasive pest and weed attacks. The fall armyworm invasion destroyed almost all of the country's maize crops in 2018.

Against this backdrop, there is a dire need to strategize on negating the Invasive and Migratory pest attack. It is worthwhile that ASSOCHAM has touched this important subject and creating platform to discuss the issues, concerns and ways to manage such disasters.

It's a pleasure to know that ASSOCHAM in association with Grant Thornton has come out with a Knowledge Paper with key recommendations on **"Strategic response to Invasive and Migratory Pests – the emerging global pandemic"** with the inputs of industry, academia and key stakeholders. I wish ASSOCHAM to keep going with such Initiatives!

(PARSHOTTAM RUPALA)

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Message

Mr. Vineet Agarwal

President, ASSOCHAM

Agriculture is the primary source of livelihood for about 58% of India's population. Gross Value Added (GVA) by agriculture, forestry and fishing was estimated at Rs. 19.48 lakh crore (US$ 276.37 billion) in FY20 (PE). Growth in GVA in agriculture and allied sectors stood at 4% in FY20.

Despite the overwhelming size of the agricultural sector, however, yields per hectare of crops in India are generally low compared to international standards. In addition to present challenges leading to low yield, the agricultural economy in India is vulnerable to threat from many potential bioweapons mainly invasive pests' species.

Invasive pest species have potential to rapidly established and spread in a new area cause major crop loss and can adversely affect food security. The spread of Invasive pest species is now recognized as one of the greatest threats to the biodiversity and economic wellbeing of the country. There is a need for interdisciplinary coordinated work among scientists Government and policy makers, in identifying invaded organisms and in assessing their ecological problems, environmental concerns in different ecosystems, economic damage and sustainable management by prevention, eradication and control.

With this background, I am pleased to present the Knowledge Paper on "**Strategic response to Invasive and Migratory Pests – the emerging global pandemic"** that has been prepared in association with Grant Thornton.

I take this opportunity to congratulate all the experts associated with the report for their contribution and inputs.

Thank you.

Message

Mr. Deepak Sood

Secretary General, ASSOCHAM

One of the critical challenges to humankind is the threat to food security due to emerging and invasive pests. Increased global trade in agriculture has increased the chances of the introduction of exotic pests. Invasive species are one of the major and most rapidly growing threats to agricultural biodiversity, livelihoods, human and animal health, forestry, and biodiversity, resulting in substantial economic losses.

Indian agriculture faces two significant challenges, i.e., production of sufficient food to feed the growing population, and prevention of environmental degradation. Damage by crop pests, including insects, diseases, nematodes and rodents, is one of the major constraints to increasing food production. Globally, up to 30% of agricultural yields are affected by pests and diseases despite intensive chemical pesticide use.

I am happy to note that ASSOCHAM in association with Grant Thornton is coming out with a Knowledge Paper on **"Strategic response to Invasive and Migratory Pests – the emerging global pandemic"**.

I am sure that this paper will provide valuable insights, and I sincerely hope the recommendation provided in this report will help the policymakers.

Message

Mr. Jaidev R. Shroff

Global CEO, UPL & Chairman, Agri Inputs & Farming Practices Council, ASSOCHAM

The global economy, with increased transport of goods and travels, has facilitated the movement of live species over long distances and beyond natural boundaries. While only a small percentage of transported organisms become invasive, they have a tremendous impact on the health of plants, animals and even humans—threatening lives and affecting food security and ecosystem health.

Invasive species constitute one of the most serious economic, social, and environmental threats of the 21st century. By producing toxins or acting as a vector for plant, animal, or human diseases, these pests may affect domestic animals, cultivated crops, forests, ornamentals, pets, wildlife and their habitats, and humans. They reproduce rapidly, out-compete native species for food, water and space, and are one of the main causes of global biodiversity loss.

Loss of biodiversity will have major consequences on human well-being. This includes the decline of food diversity, leading to malnutrition, famine and disease, especially in developing countries. It will also have an important impact on our economy and culture.

There are indirect threats of invasive species as well. Invasive species can change the food web in an ecosystem by destroying or replacing native food sources. These may provide little to no food value for wildlife. Invasive species can also alter the abundance or diversity of species that are important habitat for native wildlife.

It becomes therefore imperative to discuss this issue and strategize to mitigate the effects of invasive pest attack.

Sensing the dire importance, ASSOCHAM has organized the timely interaction and has now undertaken a study on "**Strategic response to Invasive and Migratory Pests – the emerging global pandemic"** in association with Grant Thornton**.** I hope this will pave way for apt policies and strategic response for the contingent cause!

Message

Prof. V. Padmanand
Partner
Grant Thornton Bharat LLP

Mr. Kunal Sood
Partner
Grant Thornton Bharat LLP

India is the second largest producer of agricultural commodities in the world. However, we are not competitive nor conformant either in the production and logistics, nor value-addition of agri commodities to the extent desired. This is reflected in the circumstance that we account for a small share in world trade in many commodities, even where we have huge Comparative Advantage in absolute terms in many related value-chains. The constraints may be ascribed to low productivity at the farm level, as well as some limitations in the policy and extension eco-system in the country.

While the most dynamic Central Government has evolved several PPP policies and schemes to redress constraints, today, we virtually confront a looming pandemic in terms of ongoing and potential invasion by migratory and invasive exotic pests and weeds. Evidently, this threat also affects the scope for crop diversification by farmers to more value-adding crops like groundnut and maize, for instance, in many locations.

There is, therefore, a need to evolve an apt policy framework which will be both pre-emptive as well as facilitate rapid response to invasions. Policy need be evolved in close co-ordination with private sector stakeholders and be based on benchmarked practices in other countries. A stewardship council/joint-action committee need be constituted at the earliest to evolve apt policy. Further, implementation of policy should be closely monitored in terms of entry-point quarantine, R&D initiatives, as well as related extension services on a PPP mode.

It gives us great pleasure to have served as knowledge partner to ASSOCHAM in the drafting of this Knowledge Paper on “Strategic response to Invasive and Migratory Pests – the emerging global pandemic” that is expected to kick-start related action.

We most humbly thank all industry and institutional experts associated with the report for their contribution.

Thank you.

Content

Executive summary

Invasive and migratory pests (IMPs) cause enormous and often irreversible damage to biodiversity around the world by displacing native and useful species and changing ecosystems. They cost economies billions of dollars every year, in terms of lost production, control and mitigation efforts and investment in ecosystem services. Globally, up to 30% of agricultural yields are affected by pests and diseases despite intensive use of chemical pesticides. Without natural enemies or control in the new areas they take over the ecosystem and compete with native species. Proper pest management techniques are required to mitigate such risks of pests. Some of the methods are use chemical pesticides, biological control, sterile insects and RNA interference. However, it is also necessary to evolve a defensive umbrella in terms of surveillance, global intelligence and quarantine facilities

As a matter of fact, invasive pest species have invaded and affected indigenous biota in virtually every ecosystem of the earth. Globally, insect pests have been reported to reduce agricultural yields by up to 16 per cent before harvest, and to lay waste a similar amount post-harvest. There are also some inspection and quarantine initiatives at the entry points into the country. However, it is relatively lax. The Destructive Insects and Pests Act, 1914, governs import of agricultural products. Ministry of Agriculture and Farmers Welfare (MAFW) has also prepared lists of plants whose import is allowed, restricted or banned. There is also a specified list of weeds that should not enter the country with any import. However, apparently these regulations are not stringently enforced. Approximately 6,000 known insect species, 51 animal pathogens, and 2,000 plant pathogens are recognized as established pests in the countries worldwide.

Ecological impacts occur when the local biodiversity of the area and/or the ecological processes are altered by the invasive species. In addition to that, invasive species may cause major economic losses to society, whether in the form of direct economic effects, such as loss of agricultural or fishery production, or secondary economic impacts caused by human health issues.

Apparently, the country has faced at least 10 major invasive pest and weed attacks in the past 15 years, with most recent being the fall armyworm (FAW) invasion that destroyed almost the entire maize crop in 2018. When pests, weeds, viruses and bacteria invade, they can wipe out food crops, alter the ecology, deplete water levels and cause diseases.

Government of India issued a draft order to ban 27 pesticides, and govt has further solicited feedback from multiple stakeholders. These pesticides may also have to be used in the case of some emergency situations of invasion by IMPs. In order to fight and effectively manage invasive and migratory pests, a variety of such recommendations have been prescribed by industry and institutional stakeholders in the recent past as well as in National webinar on the theme. It is important while reviewing the pesticides, a due scientific consideration be given to retain specific mode of action which is key to the resistance management and also often answer in controlling the IMP.

Notably, a Stewardship Council may be constituted to engage with all the stakeholders from the value chain that would develop a long term and sustainable plan for preparing for such attacks. Defining a long-term vision, identification of gaps / challenges in the response mechanisms, sharing related best practices and policy recommendations etc. are a few of the responsibilities that may be assumed by the Council. The Government of India also plays an anchor role in this regard to ensuring that every stakeholder is compelled to act responsibly. Apt Government policies and response is the only way to achieve a sustainable future for the agricultural economy. Such a Stewardship Council need include a range of institutions including the Directorate of Plant Protection and Quarantine Storage (DPPQS), the Department of Commerce, lead pesticide manufacturing and crop advisory firms, FPO and farmer representatives, State government institutions and MAFW. Furthermore, quarantine and import restrictions need be strictly enforced.

The Stewardship Council should also ensure that there is thrust to identifying, tracking and treating foreign pests. Academia should focus on feeding data into this repository and understanding the morphology of the pests. Periodic update should be planned with all the stakeholders involving the industry etc. In order to shorten response time and increase preparedness, communication strategies must be devised- that is harmonized between national and state level agencies. There is also necessity to regulate the movement of alien species across both ecological as well as national or political boundaries. Also, presently, there is no institutional mechanism to even probe these invasions. The MAFW responsible for the control of IMPs and Weeds, is yet to really investigate invasions till date.

There should be scope for policy level intervention which enables international cooperation for surveillance of migratory pests. India should also be prepared to tackle species that are known, however, that have not entered India yet. Further, there are some normal pests that have the potential of creating a havoc at some point- India should be prepared to face that as well.

Today, India also does not have a pest risk analysis system. The number of stations for surveillance must be increased. Efforts should also be made in the direction of integrating

1. Introduction to invasive and migrating pests and their management

1.1. About Invasive and Migratory pests

Damage by crop pests, which include insects, diseases, and rodents, is one of the major constraints in any agro-ecosystem. Globally, up to 30% of agricultural yields are affected by pests and diseases despite intensive chemical pesticide use. Apart from regular pests the agricultural economy in India is vulnerable to threat from invasive and exotic pests and diseases which act as the bottle neck in reducing yield.[i] Invasive and Migratory Pests (IMPs) are those that are non-native, have high reproductive potential, and have few natural enemies and predators to check growth in their population. Also known as alien species, these are exotic organisms that occur outside their natural adapted habitat and dispersal potential. Some of them become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and outcompete native species.

1.2. Devastating Impact

The impact of invasive pests' species is probably the biggest threat to the agro-ecosystem. Without natural enemies or control in the new terrain they take over the ecosystem and compete with native species. Concomitantly, the native species could eventually be replaced, in turn altering or even destroying the whole ecosystem. They can therefore transform the structure and species composition of ecosystem and change the way nutrients are cycled and cause negative impacts on the ecosystem, biodiversity, farmer health, cost of cultivation and yield.[ii]

The attack by IPMs is not a new phenomenon. For instance:

- Potato tuber moth is native- from Italy and was introduced in India in 1907. It is also a serious pest of stored potatoes, tobacco, tomato, brinjal and beat. Caterpillars initially mine into leaves and later make way to the stem and then to the tubers in soil. In storage 30 to 70 percent tubers are damaged significantly.
- Woolly apple aphid is a native from China and during 1920, it reached a pest status in India, damaging and desapping plants. It also attacks roots which develop swellings and whole plants even die.
- In fact, three exotic whiteflies were spotted in southern India in coconut plantations within a span of two years, rugose spiraling whitefly (2016) and Paraleyrodes bondari Peracchi (Bondar's nesting whitefly) and Paraleyrodes minei Iaccarino (2018). The spread was propelled by loopholes in the import regulations, quarantine and phytosanitary requirements and absence of regulations to control the inter-state spread. The rapid spread of rugose spiralling whitefly alone across coconut, guava and banana crops could only be controlled by its natural enemy present in India, Encarsia guadeloupae (insect parasitoid).[iii]
- Silver leaf white fly is a native from Greece and was first noticed in 1999 in Kolar district, Karnataka. The host plants of the pest number more than 900. There was also an outbreak of tomato leaf curl virus disease which resulted in failure of the tomato crop. The damage reduces plant growth rate and yield and leads to leaf chlorosis, leaf withering and premature dropping of leaves.

More recently:

Locusts destroyed tens of thousands of hectares of crops in 2019, in Gujarat. Given that locusts swarm just prior to the monsoon, this adds economic strain to a tenuous system that relies on the annual monsoon for crop success. Locust plagues also pose a threat to livestock grazers by turning grasslands into wastelands. Locusts consumes the same fodder as domestic cattle, reducing the milk quality produced by the cattle and leading to food insecurity and farmer malnutrition. In April 2020, locusts flew in from Pakistan and wreaked havoc in Rajasthan and Madhya Pradesh, sending farmers into a scurry to save their wheat and oilseed crops. Locust incursions were subsequently reported in 10 other states where operations were undertaken in coordination with State Governments for locust control. About 33 per cent of crop were damaged in several pockets.

1.3. Pest Management Methods

The various measures available for pest management at the farm level are highlighted below in brief.[iv]

- **Chemical Pesticides:** Pesticides are used globally to protect crops from damage caused by insect pests. The treatments can be effective. For example, when Volium Flexy were applied to farmers' field crops, mortality rates of the polyphagous pest Helicoverpa armigera rose to over 85 per cent, improving tomato crop yield
- **Biological Control:** Invasive insect species may thrive in a new environment because it is devoid of their natural predators. Biological control, or biocontrol, tries to remedy this by importing an invasive pests' natural predators in the hopes they will reduce invasive insect densities. For instance, first successful biological control experiment was documented in 1889 with Albert Koebele's intentional release of Australian vedalia lady beetles Rodolia cardinalis to control populations of the cottony cushion scale, Icerya purchasi. The resultant control of the crop pests was immediate.
- **Sterile Insects:** Targeting a species' reproduction is also an option. The Sterile Male Technique (SMT) involves the release of large numbers of sterile males (SMs) into a population. Females that mate with SMs will produce few or no offspring. A reduction in population size will ensue in the next generation. A technique called the Trojan Female Technique (TFT) similarly acts as a multi-generational pest suppressant, using mutations in the mitochondrial DNA (mtDNA), and inhibiting male fertility while having no effect on females. This technique could prove successful after only a single release of female insects carrying the TFT mutation, providing a more cost-effective and less labour intense avenue.
- **RNA Interference (RNAi):** RNA interference (RNAi) is a genetic method that targets a specific organism. RNAi is the process of using exogenous double stranded RNAs (dsRNA) to target specific messenger RNAs (mRNAs) for degradation, which result in silencing the gene's expression. Feeding insects transgenic plants containing dsRNA has also been proven a useful method of pest control for crop protection against the western corn rootworm, and a dsRNA enriched diet is proven to be a successful pest control of the pea aphid Acyrthosiphon pisum, regardless of life stage.

2. Empirical evidence and case illustrations on the threat of Indian Context

Invasive species may transform the structure and species composition of ecosystems by repressing native species, or by changing the way nutrients are cycled through the system. The result may be an irretrievable loss of native species and ecosystems.

Invasion by alien organisms may be considered in the following steps:

- **Introduction:** Some non-native species are imported intentionally, but others arrive unintentionally in shipping containers, infesting fruits carried by tourists, or in their muddy footwear, or hidden in the soil of imported ornamental plants. They can also invade through long-distance migrations or movements (e.g. the brown planthopper, in rice), transportation such as in the case of Parthenium along with wheat grains in India, or aquarium plants such as water fern.
- **Establishment:** Once the invaded species has overcome the environmental barriers in the introduced area, it establishes itself and populations are sufficiently large and chances of local extinction by environmental factors is ruled out.
- **Spreading:** The spreading of a species into areas away from the initial sites of introduction requires that the introduced species have also to overcome barriers to dispersal within the new terrain.
- **Naturalization:** Naturalization starts when abiotic and biotic barriers to survival rate are surmounted and barriers to regular reproduction are overcome.

2.1. Case Illustrations on the scope and scale of invasions in India

Many invasive pests including Fall Armyworm invaded Indian agriculture have caused enormous food losses and posed a great threat to India's food security and farm prosperity. Besides pests, the entry of some invasive weeds has also created headaches for farmers. In the recent past, the invasive 'Onion Weed', a native of North Africa, Southern Europe, and West Asia, has invaded onion farms in Ahmednagar and Aurangabad districts in Maharashtra. This weed, can potentially damage India's self-sufficiency in onion production. This weed could also make land infertile if it is not controlled timely.

Fall Armyworm

The attack of Fall Armyworm on maize crop in Chittoor district of Andhra Pradesh has not just affected farmers, but also cattle. The has several areas that are unable to generate enough fodder after the pest attack. In many regions yield was 18 to 20 tonnes of maize per acre. The worm was first sighted in AP in August 2018 in Srikakulam and Vizianagaram districts. The worm has attacked other districts since then the worm can wreak havoc on around 80 crops especially cereals. Agricultural universities have also been of the view that maize mono cropping need to be twinned judiciously with other non-susceptible crops. Prolonged monoculture, supported by powerful pesticides, destroy the natural enemies of the pest. Long and dry spells coupled with too many bouts of overcast sky have made maize susceptible to pest attack. The FAW prefers maize but can also feed on more than 80 other crops, including wheat, sorghum, millet, sugarcane, vegetable crops and cotton. Once established in a country, FAW is difficult to eradicate or control it from spreading – an adult can fly up to a hundred kilometres in a single night.[v] In 2019, the pest has spread as far as Mizoram in the northeast, Uttar Pradesh in the north, Gujarat in the west, Chhattisgarh in central India, and several states in the south. In 2020, the biggest victims so far have been farmers in the north-eastern states. The pestilence has been reported from 20 states in India.[vi]

Papaya Mealy bug

The infestation was first noticed in 2007 on Papaya, at Coimbatore, Tamil Nadu. By 2009, the pest assumed the major pest status across the country and caused huge damage to mulberry, tapioca, Jatropha, cotton and several fruits, flowers and plantation crops in Tamil Nadu causing 90 per cent damage. Fortunately, the pest could be successfully managed through the intervention of biological control through Acerophagous papayae which was imported from the USA.

Subabul psyllid

A native of Cuba and Central America, this spread to Sri Lanka and the Tamil Nadu and Karnataka by 1988. It sucks the sap from young shoots and leaves which results in the complete deformation of young shoots. In severe cases, the plants could not recover. In Karnataka, Leucaena cultivation planned in a large area was given up due to fear of attack.

In 1988, the ladybeetle, Curinus coeruleus Mulsant (Coleoptera: Coccinellidae) from Mexico was introduced into India for biological suppression. The predator has since successfully established in Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu.

Blue gum chalcid

The blue gum chalcid is a gall-inducing wasp native to Australia. It has become a pest of planted eucalyptus in various parts of the world including Kenya, Morocco, New Zealand, Tanzania and Uganda. It has spread to India in planted forests and nurseries of Eucalyptus. Repeated attacks lead to loss of growth and vigour in susceptible trees. The likely source of introduction of this pest insect to India could be through exchange of vegetative materials of eucalyptus. Care needs to be taken to incorporate appropriate genetic diversity with periodic introductions and phasing out of different clones.

Erythrina gall wasp (EGW), is an invasive insect pest in major black pepper, areas of Kerala and Karnataka. EGW was first reported damaging. in Taiwan in 2004 and was recorded in India in Kerala and Maharashtra in 2006.

Brown-tail moth

The caterpillar or larval stage of the Brown Tail Moth is dark brown with a dotted white line down each side of its back. It has two prominent red dots on the back of its tail. The most likely period of contact with the unsuspecting is in May and June when the caterpillars forage further from their cocoons. The caterpillars can cause complete foliage loss of a wide variety of shrubs and trees including hawthorn, blackthorn, apple, pear, plum, and ornamental cherries.

Codling moth

Codling moth is an insect pest of apple, distributed in the apple growing areas of Ladakh. It causes tremendous loss in the yield due to direct fruit damage. If left unchecked, the extent of infestation may be up to 80 per cent in apple. It is believed to have entered this part of India from Pakistan and Afghanistan. With the extensive damage and continued scourge by this pest in Ladakh region, it was declared as a quarantine pest, decades back, hence the implementation of the strict embargo on the transportation of apple outside Ladakh, as a safety measure for other apple-growing areas of Jammu and Kashmir and also adjoining Himachal Pradesh.

High incidence of Codling moth in Ladakh is attributable to reasons such as naturally grown wild varieties of apple, very tall and inaccessible apple trees for management and lack of adoption of GAP amongst others.

Migratory weeds

Agriculture today not only faces issues due to native weeds, but also due to exotic weeds, which also enter through the import route. India has faced several such incidents of invasive alien weed species in the last century, such as Chromolaena odorata, Lantana camara, Prosopis juliphlora, Argemone mexicana, Mikania micrantha, Eichhornia crassipes, Salvinia molesta etc. There are 31 weed species regulated as quarantine weeds under Schedule-VIII of PQ Order 2003 in addition to weeds associated with various commodities and pathways mentioned in Schedule VI. Proper identification of weed species and more stringent import norms for preventing their entry is the need of the hour. Bulk imports and close similarity in morphological traits of these weeds with the import crop makes the task even more difficult.[vii]

One such weed is Phalaris minor (Littleseed canarygrass), and it effectively uses the environmental and management conditions of both wheat and rice in the rice–wheat system to its advantage. No herbicide has been able to provide effective control as regeneration is observed in almost all the cases. Tillage, crop residue management, and spatial–temporal considerations have nevertheless led to some control on the pernicious weed.[viii] Notably, it poses a grave threat to the very sustenance of wheat cultivation in North India.[ix]

Migratory locust

Migratory locust has emerged for the first time as a serious pest in Changthang Valley (Leh District) and Zanskar Valley (Kargil District) in Jammu and Kashmir State, India, in 2006. The infestation of migratory locust was found both in cropped and pasture areas. No crop loss has been reported in Changthang Valley due to locust, but 90 per cent of crop damage has been reported in Zanskar.

Recent Incidents

The 2019-20 locust attack in Gujarat, Rajasthan and Madhya Pradesh as well as other states is a more recent illustration.

Table 1: Invasive and Migratory Pests to India in the last 20 years

#	Invasive pest	Year of attach	Host country / Region of Origin	Host Crop	Area of damage in India
1	Onion weed	2019	Africa, South Europe, West Asia	Onion	Maharashtra
2	Double gee	2019	South Africa	Wheat	Haryana
3	Fall Army Worm	2018	North and South America	Maize	Major parts of the country
4	Rugose Spiraling Whitefly	2016	Central America	Banana, Coconut, Mango, Jackfruit	Kerala
5	Coffee Berry Borer	2014	North America	Coffee	Kerala, Karnataka, Tamil Nadu
6	Tomato Leaf miner	2014	South America	Tomato	Andhra Pradesh, Chhattisgarh, Karnataka, Tamil Nadu
7	Eriophyid mite	2014	South America	Coconut	South India, West Bengal, Odisha, Gujarat, Maharashtra
8	Papaya mealy bug	2012	North America	Papaya	Assam, West Bengal, Rajasthan, Karnataka, Kerala, Tamil Nadu
9	Eucalyptus Gall Wasp	2009	Europe	Eucalyptus	Karnataka
10	Cotton Mealy Bug	2004	North America	Cotton	Punjab, Haryana, Maharashtra, Tamil Nadu, Karnataka, Madhya Pradesh, West Bengal, Gujarat

3. Empirical evidence and case illustrations on the threat of Global Context

Apparently, invasive insects cost the World economy a minimum of US $ 70.0 billion per year globally, while associated health costs exceed US $ 6.9 billion per year (Bradshaw et al. 2016).

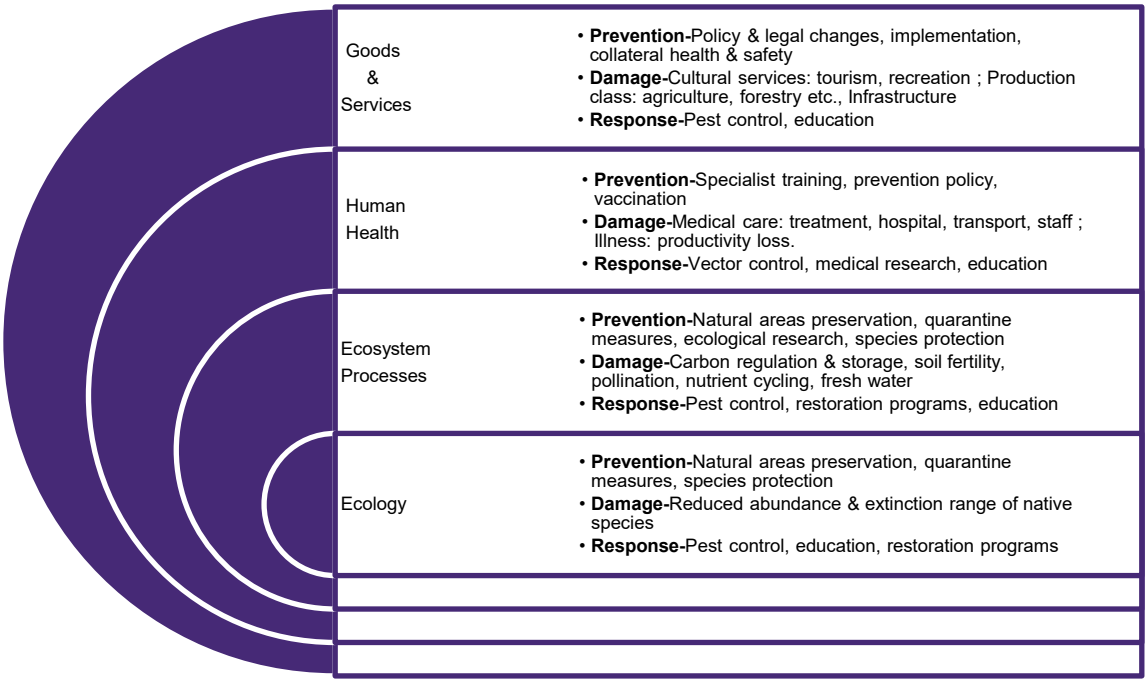

Figure 1 Global costs of invasive insects[x]

The numbers of invasive species in a region or country have consistently been shown to be related to gross levels of trade.

Approximately 6,000 known insect species, 51 animal pathogens, and 2,000 plant pathogens are recognized as established pests in the countries worldwide (except USA- data not available).

Table 2: Global pests potentially damaging to plants and their source

Scientific name	Common name	Potential source
Insects		
Adelges japonicus	Spruce gall aphid	Japan
Agriotes obscurus	Dusky wire worm	Canada, Europe
Agriotes sputator	Common click beetles	Canada, Northern Europe
Anoplophora glabripennis	Asian long-horned beetle	China, Japan, Korea
Aradus cinnamomeus	Pine flat bug	Europe
Calliteara pudibunda	Dog hop	Europe
Ceratitis capitata	Mediterranean fruit fly	Africa, Central and South America, Europe

Cryptomermes spp.	Drywood termite	Africa, Asia, Central America
Dendroctonus spp.	Bark beetle	China
Eutetranychus orientalis	Citrus brown mite	Africa, Asia, Australia, Middle East
Helicoverpa armigera	Cotton bollworm	Africa, Asia, Australia, Europe, Middle East, Pacific Islands
Hylurgops major	Pine bark beetle	China
Hylurgus ligniperda	Red-haired pine bark beetle	Africa, Asia, Australia, Brazil, Europe
Lesidosaphes newsteadi	Pine pest	Cuba
Lymantria dispar (Asian)	Asian gypsy moth	Eurasia
Lymantria monacha	Nun moth	Asia, Europe
Panolis flammea	Pine beauty	Europe
Sarsina violascens	Purple moth on eucalyptus	Argentina, Brazil, Mexico
Scolytus intricatus	European oak bark beetle	Africa, Asia, Europe, North Africa
Targionia vitis	Pest on grape	Mediterranean area
Tomicus piniperda	Bark beetle	Asia
Xyleborus spp.	Bark beetle	China
Fungi		
Armillaria spp. (exotic)	Root and heart rots of trees	Africa, Asia, Australia, Europe, South America
Ceratocystis autographa	Wood rot of conifers	Europe
Chrysomyxa himalensis	Rust on rhododendron	India
Colletotrichum zeae	Anthracnose	Africa, Europe, Nepal
Cronartium himalayense	Pine rust	Asia, India
Ganoderma spp. (exotic)	Root and wood rots of trees	Africa, Asia, South America
Helicobasidium mompa	Wood rot of fruit trees	India, Japan
Lachnellula willcommi	Larch canker	Europe
Lophodermella sulcigena	Needle cast of pines	Eastern Europe
Melampsora pinitorqua	Twist rust of pines	Europe
Microcyclus ulei	Leaf blight of rubber	Central and South America
Moniliophthra (Monilia) rorei	Pod rot of cacao	Central and South America
Mycosphaerella sojae	Soybean brown spot	Asia

Ophiostoma spp. (exotic)	Wilt and wood rot of tree	Asia, Europe
Peronosclerospora maydis	Java downy mildew, corn	Australia, Indonesia
Peronosclerospora philippinensis	Philippine downy mildew	India, Indonesia, Philippines
Peronosclerospora sacchari	Downy mildew	Australia, Fiji, India, Japan, Philippines, Taiwan
Phakopsora pachyrhiza	Soybean rust	Africa, Asia, Australia, Central and South America, Mexico, Pacific Islands
Phellinus spp. (exotic)	Root and wood rots of trees	Africa, Asia, Australia, Europe, South America
Pucciniastrum areolatum	Cherry spruce rust	Europe
Pythium volutum	Root rots of barley, ginger	Europe
Sclerophthora raysiae	Downy mildew	India, Nepal, Thailand
Septoria maydis	Ear and stalk rots of corn	Central and South America
Synchytrium dolichi	Gall on Fabiaceae	Africa, Asia, Central America, Philippines
Bacteria and phytoplasmas		
Corynebacterium tritici (C. rathayi)	Yellow slime disease	Australia, Europe, India, Middle East
Flavescence doree (maladie du Buco 21)	Phytoplasma of grape	Europe
Phytoplasma	Apple proliferation	Europe
Xanthomonas axonopodis Pv. citri	Citrus canker	Asia, Australia, India, Indonesia, Mexico, South Africa
Xanthomonas axonopodis Pv. vasculorum	Sugarcane gumming disease	Africa, Australia, Central and South America, Philippines
Viruses (and Virus-Like Particles)		
Banana bunchy top virus	Banana bunchy top virus	Africa, Asia, Australia
Begomovirus complex	Begomovirus complex (New types and vectors)	Asia, Caribbean, Worldwide
Citrus ringspot virus	Citrus ringspot virus	Argentina
Citrus tristeza virus	Citrus tristeza virus (CTV, new strain)	Asia, Caribbean
Groundnut rosette virus	Groundnut rosette virus	Africa, Australia, Philippines
Plum pox virus	Plum pox	Chile, Europe, India
Soybean stunt virus	Soybean stunt	Asia

Nematodes		
Globodera rostochiensis	Golden nematode of potato	Africa, Canada, Central and South America, Europe, Japan

Global pests potentially damaging to plants and their source[xi]

3.1. Case Illustrations in the Global Context

Asian Hornet

Vespa velutina nigrithorax is an Asian hornet native to China that invaded South Korea in 2003 and France in 2004. Introduced from China, it invaded most of the peninsula at an approximate rate of 10-20 km per year and became more abundant than other native Vespa species. The invasive hornet was then introduced into Japan. In France, was first observed in 2004 after its accidental introduction from China. It spread rapidly, colonising most of France at an approximate rate of 60-80 km per year and progressively invading other European countries, and the UK where it was first recorded in 2016. The species can rapidly spread on its own. Both climate and land-use may propel distribution.

Fall Armyworm

More recently, the fall armyworm (FAW) has successfully invaded the African continent, spreading to all sub-Saharan nations, Madagascar and the Seychelles by 2018. In May 2018 it was confirmed on the Indian subcontinent and Myanmar and Thailand in same year 2018. Its movement to India may have been due to natural migration assisted by wind currents.

Cotton Bollworm

The spread of cotton bollworm moth throughout South America highlight the invasiveness and adaptability of moths in the genus. Long-range movement occurs by migration and international trade. The ability to track long-distance movement through radar technology, population genetic markers, and/or long-distance dispersal modelling has advanced in recent years, yet we still know relatively little about related population trajectories or migratory routes.

4. Typologies of IMPs and the nature and extent of devastation

Invasive and migratory pests (IMPs) cause enormous and often irreversible harm to biodiversity around the world by displacing the native and useful species and changing ecosystems. They are responsible for the extinction or decline of many species and continue to pose a huge threat to many more. They cost economies billions of dollars every year, in lost production, control and mitigation efforts and investment in ecosystem services.

The understanding and management of IMP continues to evolve. Terms such as alien, invasive, weed, introduced, feral, exotic and more are often used interchangeably.

Alien species – a species that has been intentionally or unintentionally introduced to a location, area, or region where it does not occur naturally.

Invasive species – a species that has established and spread or has the potential to do so, outside of its natural distribution range, and which then threatens ecosystems, habitats and/or other species, potentially causing economic and/or environmental damage, or harm to human health. The majority of invasive species are alien. However, native species may also become invasive, usually under altered environmental conditions such as grazing, cyclones, changes in nutrient regimes, colonisation by an invasive species. For example, the native water plant hippo grass has become invasive in many African water bodies following an invasion of alien species such as water hyacinth.

Invasive and migratory pests (IMP) – an IMP species that has established and spread, and which causes, or has the potential to cause, harm to the environment, economies, or human health.

4.1. Defining Pathways

A pathway is broadly defined as the means (e.g. aircraft, vessel or person), purpose or activity (e.g. farming, shipping or pet trade), or a commodity (e.g. fisheries) by which an alien species may be transported to a new location, either intentionally or unintentionally. This differs from a vector, which is the actual physical means, agent or mechanism, which enable the transfer of organisms or their propagules from one place to another. Hence, a tourist carrying seeds in muddy footwear is a vector, whereas tourism and international flights are the pathways. Note that species can also expand their range through natural means. For example, birds can fly or be blown by storms to new locations. Some species or their propagules may be moved to new locations by wind, currents and in or on animals. This is referred to as natural dispersal and not an introduction. Natural dispersal may also contaminate to subsequent spreading of an alien species once introduced to a new region or country.

4.2. Types of Alien Species

Intentional introduction falls into two categories: authorised and unauthorised[xii].

- **Authorised:** The introduction of species in this category is planned and (ideally) formally approved. This formal process is designed to try and ensure that the species being introduced does not become invasive. Distinction should be made between:
  - Species that are directly introduced into the wild for economic reasons (e.g. crops, domestic animals, or plants intended to improve soil condition, provide fuelwood/pasture or prevent erosion). These species are introduced with the purpose and intention of them establishing in their new field.

  - Species that are introduced into captivity (e.g. zoos, botanical gardens, aquaculture, pets, farmed These species are not meant to be released into the wild but be kept in captivity. Nevertheless, escapes.

- **Unauthorised:** Smuggling of plants, animals, seeds and foodstuffs such as meat and meat products, fruits and vegetables are a serious problem worldwide. There may also be instances where there is not an authorisation process in place for regulating alien species introductions. For example, some countries may regulate the movement of alien species across their political borders but not within the country itself.

4.3. Loss and constraints

Ecological

Ecological impacts occur when the local biodiversity of the area and/or the ecological processes are altered by the invasive species. IMPs affect native biodiversity through:

- Direct predation
- Competition for resources, such as nesting sites (for birds), light (for plants) or preferred food/nutrients
- Habitat alteration, such as shading out native species and freshwater systems, increasing erosion, permanently altering nutrient cycles or soil properties
- Spreading pathogens and parasites
- Upsetting ecological balances and interactions, such as producing flowers that are more attractive for pollinators or causing native prey populations to decrease to the extent that they can no longer cope with natural predation rates.
- Degrading the environment so that further invasions are facilitated.

While the costs of prevention, control and mitigation measures to avoid biodiversity impacts can be measured, the actual value of an extinct species or a change to the ecosystem is harder to quantify.

Economic

Invasive species may cause major economic losses, whether in the form of direct economic effects, such as loss of agricultural or fishery production, or secondary economic impacts caused by human health issues. Imps change ecosystems in ways that affect flooding, erosion and silt accumulation, water quality and air quality. These are not so easily quantified and are often excluded from the analysis of costs associated with IMPs. Some estimates:

Country	Cost (USD Billion)
Brazil	50
India	117
South Africa	12
United Kingdom	12
United States	137

4.4. Pesticide Resistance

Pesticide resistance in agricultural pests in India was first noticed in 1963, when Singhara beetle, *Galerucella birmanica*, from Delhi was reported to be resistant to DDT and HCH. Globally, insect pests have developed resistance to all major classes of pesticides.[xiii]

The Diamond Back Moth (DBM), *Plutella xylostella L.*, is a common lepidopteran pest of cole crops and other Brassica species, with a long history of resistance to insecticides starting with DDT in 1953.[xiv] Apparently, intensive insecticide use creates an environment free of natural enemies in which pests with capability of insecticide resistance could thrive. The species has the distinction of being the only known pest species to evolve resistance to Bacillus thuringiensis (Bt).[xv] In this context, a few options for countering pesticide resistance include:

- Judicious use of pesticides and pest monitoring.
- Use of synergist to make pesticide more effective by inhibiting the detoxification mechanism.
- Alternate use of chemicals with different mode of action, it is important to retain multiple mode of action for an effective resistance management strategy.
- Various cultural and biological methods also reduce dependence on chemical use.

4.5. Limitations in the monitoring eco-system

The country has experienced more than10 major invasive pest and weed attacks in the past 15 years, with the latest being the fall armyworm that destroyed almost the entire maize crop in 2018.

Invasive pests and weeds can enter a country by flying over the border or by growing gratuitously. Checking their entry is difficult. However, when they enter through airports and dockyards in cargos of imported grain or with items carried by tourists, the authorities should present their entry.

For this reason, unlike in India countries have stringent animal, plant and health quarantine facilities including for agriculture products at all trans-border entry points.

In India today apparently, there is no institutional mechanism to even probe these invasions. The Union Ministry of Agriculture and Farmers Welfare (MAFW), which is responsible for the control of invasive pests and weeds, has not investigated any invasions to the extent required, till date. The Directorate of Plant Protection and Quarantine Storage (DPPQS), Faridabad, Haryana, is an institution whose services may be twinned. In this regard there should be a cell at MAFW to catalogue, monitor and investigate the influx of exotic pests and weeds.

4.6. Quarantine and import restrictions not stringently enforced

There are some inspection and quarantine initiatives at the entry points into the country. The Destructive Insects and Pests Act, 1914, governs import of agricultural products. The country has 108 plant quarantine centres located at major airports, seaports and trans-border railway stations. The check posts at these quarantine centres are under the control of the Central Board of Indirect Taxes and Customs (CBITC), which works in close coordination with DPPQS. When an agricultural product arrives, customs officials check if it has a phytosanitary certificate. The government of the exporting country issues this certificate, showing that the product is without any pest or weed infestation. If the product is certified, it is cleared by DPPQS after a sample test. If the product has not been given a phytosanitary certificate, the foreign government is obliged to inform India, in which case DPPQS fumigates the product

with methyl bromide and issues a phytosanitary certificate. The fumigation is for two to 48 hours and depends upon the volume and quality of the product, and the country of origin. The company is charged for the fumigation.

MAFW has also prepared lists of plants whose import is allowed, restricted or banned. There is also a list of weeds that should not enter the country with any import. However, apparently these regulations are not stringently enforced.

Non-operational quarantine centres

Moreover, only 57, or only half of India's plant quarantine centres, are functional. Rest are non-import-export is negligible or because of staff shortage. "Customs officials also often release the cargo without referring it to DPPQS.

5. Some initiatives to manage invasive and migratory pests

Several massive efforts are being taken to control the spread and mitigate effects of FAW. Some of the measures taken by the Ministry of Agriculture and Farmers Welfare include[xvi]:

- The Indian Council of Agriculture Research has prepared a detailed Package of Practices (POP) against FAW in Maize crop. The POP, inter-alia, contains mechanical, cultural, biological and chemical measures to control FAW. The POP has been circulated to all the States for its implementation. Timely advisories are being issued regularly to State Departments of Agriculture to adopt preventive measures.
- A High-Power Committee (HPC) has been constituted, headed by the Secretary (DAC&FW) and Secretary (DARE) to review the status and to recommend appropriate strategies. Based on the recommendations of the HPC, various Sub-Committees have also been constituted in several states.
- Regular surveys, surveillance and monitoring were conducted by the Central Integrated Pest Management Centres (CIPMCs) in collaboration with the State Department of Agriculture, SAUs and ICAR etc. Further, awareness programmes for the farmers were organized. Certain Bio-control Agents have found effective against FAW. Mass production of these bio-control agents has been promoted.
- Union Minster of State for Agriculture and Farmers' Welfare launched a dedicated website (www.fallarmyworm.org.in) in2019 to help farmers fight against the dreaded Fall Armyworm (FAW).[xvii]

In fact, the efforts have been international.xviii FAO's Regional Office for Asia and the Pacific (RAP) and the Agriculture Plant Production and Protection Division (AGP) brought together government representatives from twenty countries in the Asian region, FAO staff from countries, and resource persons from the Asian, African and other regions to exchange information and develop best strategies and action plans for sustainable management of the FAW that is likely to spread further in the Asian continent.

Corteva Agriscience[xix], also launched a new insect-control solution to tackle the Fall Armyworm infestation in India. Over 30 scientists from global agricultural research institutes have joined forces to combat the spread of Fall Armyworm (FAW) in India. Equipped with a real-time tracking tool, they are set to take on the highly invasive pest with an early warning system for farmers and policymakers alike. The Farmer app, Plantix Pest Tracker, receives 20,000 images every day from across India, and the data is used to derive insights by tethering all coordinates to a 10 km radius. Scientific staff from the Progressive Environmental and Agricultural Technologies (PEAT), Centre for Agriculture and Bioscience International (CABI), and ICRISAT, have been leading the efforts with support from State governments and other research partner institutions.[xx]

6. Recommendations of industry leaders and experts on options for India: The way forward

Programme deliberations in the National Webinar Inaugurated by Hon. Minister of State for Agriculture Shri Purushottam Rupala offered some insights on the way forward. In order to fight and effectively manage invasive and migratory pests, a variety of recommendations have been prescribed by industry and institutional stakeholders in the webinar.

- About 30% loss occurs due to pests. Today, the threat of food security is the biggest threat that faces the country. Even a single invasive pest can lead to a calamity for marginal and small farmers.
- We need to address the new dimension of the role of agro-chemicals in controlling the impact of invasive pests. “Emergency response” is not a sustainable measure. We need to evolve a progressive response system in the country. For this, we may need to import technology and institutionalise response to such pest invasions by the government. A Stewardship Council represented by all leading institutional and industry stakeholders is the need of the hour. MAFW should take the lead in constituting such a council or forum involving all relevant stakeholders in the value chain ranging from entry point authorities, agricultural universities, research stations, DPPQI, MoFPI, MoC & I to leading input and crop advisory providing firms. Preparedness for tackling invasions is the need of the hour.
- There is scope to derive learnings from Project SAFFAL. Project SAFFAL is one initiative in the direction of tackling the specific pest of Fall Armyworm (FAW). The Project is a multi-year project and aims at safeguarding agriculture and farmers against the fall armyworm in India. The project was headed by the South Asia Biotechnology Centre (SABC). The project basically, calls upon stakeholders to work together, including farmers, the scientific community, SAUs and the government at the Centre and States in tackling the highly destructive pest. The project with its salient features intends to address the knowledge gap, comprehend the nature of the fall armyworm, its biology, life cycle, feeding habits, adverse economic impact, distribution and migration, and host-pest interactions, organize farm demonstrations in collaboration with both public and private sector institutions to showcase IPM package of practices and build capacity & skills of smallholder farmers in India and across Asia. In a nutshell, the project SAFFAL aims at developing a suite of techniques, good agricultural practices and control measures along with educational material for various stakeholders to enhance farmers’ preparedness to tackle the menace of the FAW. The organisation has tied up with over 35 government and international agencies (approx. 35). More than 6000 workers have been trained through this. The web-based portal which all the repository of information is available on: www.fallarmyworm.org.in

The management measures may be viewed in three steps:

  - When the pest has not been introduced: Preventive measures are taken to avoid the entry of the invasive insect, viz. pest risk analysis (PRA), quarantine and monitoring. This is the best way in managing the invasive species. Import of agricultural products is governed by the Destructive Insects and Pests Act, 1914, and 108 plant quarantine centres (located at major airports, seaports and transborder railway stations) under the control of the Central Board of Indirect Taxes and Customs (CBITC) and supported by Directorate of Plant Protection and Quarantine Storage (DPPQS), are responsible for checking phytosanitary measures. Unfortunately, however, issues related to staff shortage and non-referring the cases to DPPQS by customs are rather common and only 57 such centres are apparently working in India. The situation in the

animal quarantine centres is no different. There is a need for quarantine system overhaul. Ministry of Agriculture and Farmer Welfare has lists on agricultural products whose import is allowed, restricted or banned, and agricultural imports have to be made more compliant.[xxi] Capacity building of quarantine officials, particularly in detection of invasive species is required. Guidelines also require to be updated with new invasive species.

  - When the species is introduced but is not spread to nearby areas: Post quarantine measures are taken in such cases such as rejection of the consignment from which the pest has introduced and eradication by means of fumigation of the consignment lot.
  - When the introduced insect has established itself: Various curative measures such as cultural, biological and chemical means of management are adopted.[xxii]

- There is need also to draft a policy for effectively managing migratory and invasive pests.
- There is need to coordinate with international agencies to deal with pest attacks that entail the pest traveling across multiple countries. We hope such international coordination would help in early preparedness for probable pest attacks.
- The Indian food system is very fragile, because the agriculture community reacts rather than being proactive. Although, when Fall Armyworm got introduced in India, the reaction of the government was very positive, as they received a many registration for the molecules. However, such a response should be institutionalized by the government.
- India should focus on importing the latest technologies from other countries as soon as possible. Collaborative efforts across borders will make a big difference. Finally, integrated pest management should be adopted as a proactive step which would prevent 'emergency' reactions.
- Networking of various agro bodies should take place in order to quickly detect probably invasive pest infestations. Specifically, mapping of breeding areas during pest migration needs to take place. This will enable targeting breeding grounds and limiting their expansion.
- Further, bio pesticides should be looked at as a means of dealing with the invasive pests. There should be a regulation that allows enabling biologicals to be introduced in India. Increasing ease of introduction of these species would help the agriculture community survive through events of invasive pests.
- There should be scope for policy level intervention which enables international cooperation for surveillance of migratory pests. India should also be prepared to tackle species that are known, however, that have not entered India yet. Further, there are some normal pests that have the potential of creating a havoc at some point- India should be prepared to face that as well.
- Currently, India also does not have a pest risk analysis system. The number of stations for surveillance must be increased. Efforts should also be made in the direction of integrating scientific community with the industry for better preparedness and easier transfer of knowledge.
- The Stewardship Council should also ensure that there is thrust to identifying, tracking and treating foreign pests. Academia should focus on feeding data into this repository and understanding the morphology of the pests. Periodic update should be planned with all the stakeholders involving the industry etc. In order to shorten response time and increase preparedness, communication strategies must be devised- that is harmonized between national and state level agencies.

7. Constitution of Stewardship Council with examples and operational and funding mode

7.1 About Stewardship Council

Stewardship Councils are typically constituted to engage with all the stakeholders from the value chain such as Government bodies, Processors, Exporters, Industry leaders and Institutions that would develop long term and sustainable plans. The Council actively facilitates public private dialogues and develop an effective mechanism that would also advise the government on policy and regulatory matters and support in implementation of related programmes.

7.2 Roles and Responsibility of the Stewardship Council

- Defining a long-term vision for the sector/issue and working towards it including all important stakeholders
- Identification of performance/efficiency gaps and devising strategies to plug these gaps
- Share best practices and failures through a collective learning culture and act upon results and are in still continuous improvement
- Linking all the stakeholders
- Policy communication
- Dissemination of findings/activities through events and publications to the public at large
- To secure government support and financial support for various activities
- Support research, evaluations and technical support to inform and support the agenda of the council.
- Adopting innovative and proactive approaches and processes to enhance women's meaningful participation in partnerships, decision-making, leadership roles, and benefits.
- Promoting development and access to innovation and new technologies, combined with traditional knowledge, to attract and enable youth to be drivers of improvement in agriculture and food systems

7.3 Roles and Responsibilities of the Government

Government plays an anchor role and ensures that every other stakeholder is compelled to act responsibly. A Stewardship council will provide agri-business stakeholders and government with a common language to engage and collaborate on common objectives.

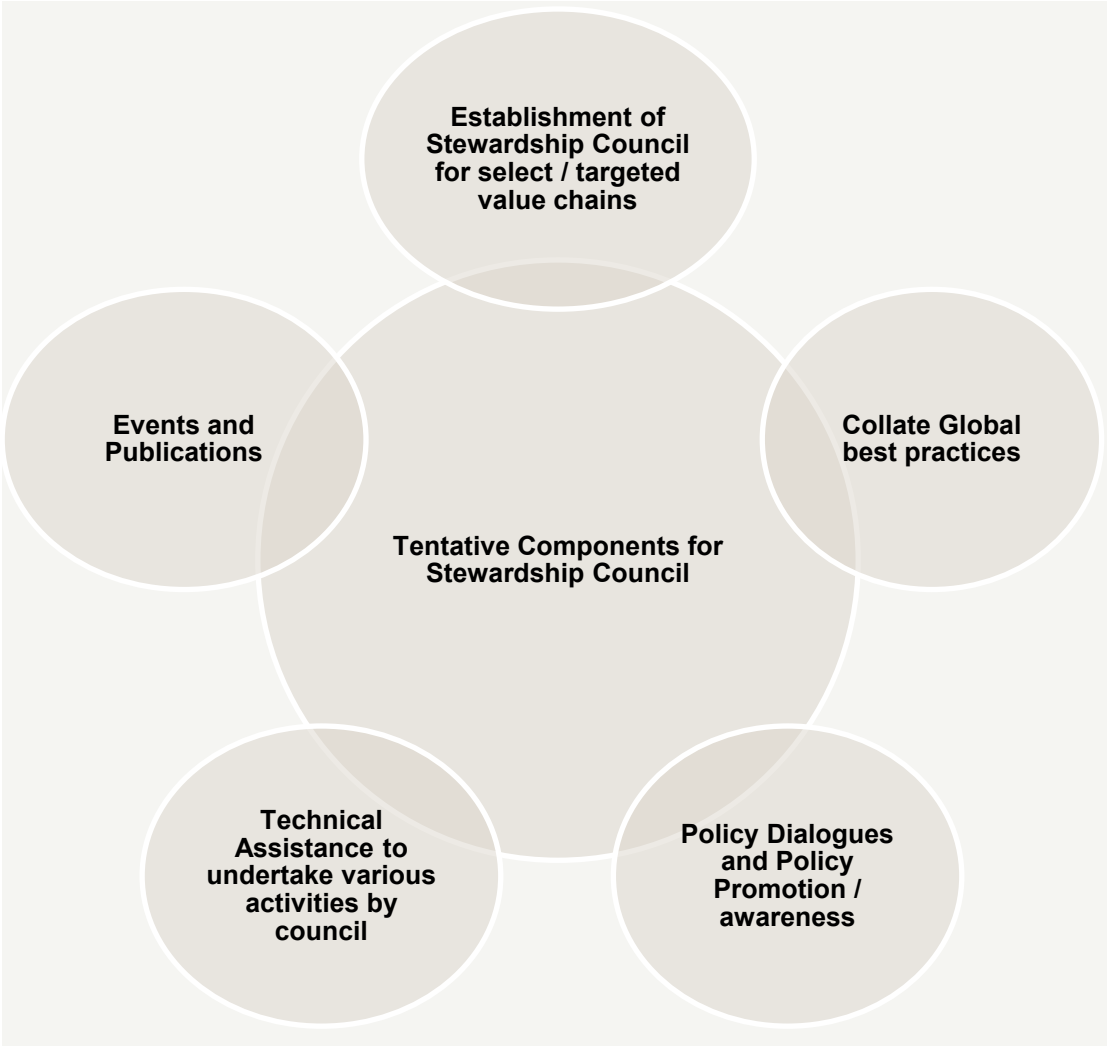

Figure 2: Tentative Components for Stewardship Council

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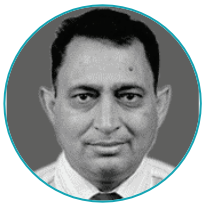

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Together, we can make a significant difference to the burden that our nation carries and bring in a bright, new tomorrow for our nation.

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