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Forest-Invasions: Restoration of Forest Ecosystems Affected by Invasive Plant Species Lantana in Corbett Tiger Reserve of India

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FIG. 1 Typical Lantana Camara Species Source: Google

***Abstract*: Lantana is one of the worst weeds of South American origin that has threatened native biodiversity of forest ecosystems across India. It was introduced into India as a garden ornamental plant in the 19th century and now it has spread over all the tropical and subtropical regions of India. Various attempts have been made by forest department of India to control Lantana by physical, chemical and biological methods; but there is no success in its control and the prevention of its spread. No effective management strategy was available to limit and stop the spread of this alien weed. The assessment of the biological and ecological systems of Lantana is studied by the team and has developed a new management strategy. The new strategy developed has been implemented successfully in plots of 2–5 hectares at the Corbett Tiger Reserve (Uttarakhand).**

Keywords: Invasions, Ecological Restoration, Lantana (Lantana camara), Cut rootstock method, Corbett Tiger Reserve

INTRODUCTION:

Invasive non-native plants can contribute directly to the degradation of ecosystems or they has indirectly affected the global climate and thus posing threat to the survival of living beings. Ecological restoration is the application of ecological principles to return the ecosystem of native trees in Corbett tiger reserve and the tiger habitat.

1. **Ecological Restoration Approaches In Corbett Tiger Reserve:** Removing weeds or reinstating a natural disturbance in the tiger reserve was a must needed. The forest department team has studied the practice of restoring degraded ecological systems affected by invasions. Enhancement of various ecosystem services and re-establishment of ecological integrity which lost was their motto, further by bringing back the native species, the deliberate removal of invasive alien species lantana. The ecological restoration is thus aims to recover its structure i.e. species composition, soil and water properties and functional properties i.e. productivity, energy flow, nutrient cycling. Allow natural recovery and recover the ecological service system in the tiger reserve.
   Lantana has many adverse affects on forest ecosystems which include (i) loss of native biodiversity (ii) replacing native plant communities in forests ecosystems by forming dense impenetrable thickets, (iii) contributing to erosion of soil, (iv) adversely impacting the regeneration of forests, (v) harboring vectors that carry infectious diseases and (vi) promoting fire hazard.

- **Study Weed Composition**
- **Access Energy Flow And Nutrient Cycling**
- **Inspect Properties Of Degraded Soil And Water**

FIG. 2 Restoration Approaches For Corbett Tiger Reserve Source: Author

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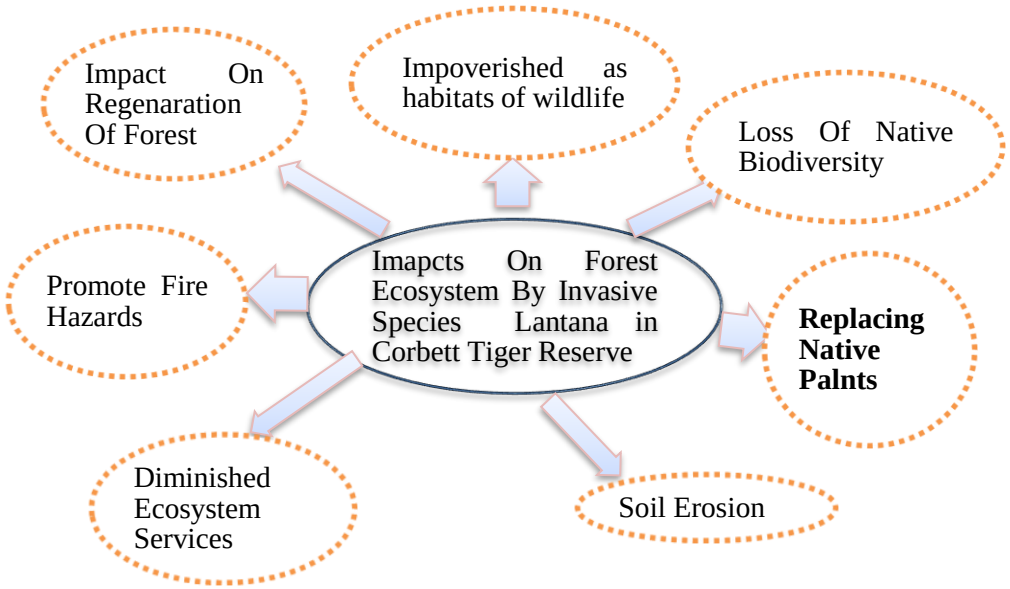

Fig. 3 Factors Influencing the Degradation of Forest Systems in Corbett Tiger Reserve, India SOURCE: Author

2. CONCEPTUAL SCHEME ANALYSIS BY FOREST DEPARTMENT :

Propagule flow of invading **Lantana** is indicated in black balls. The size of upper three arrows indicates the intensity of control efforts required to stem propagule flow of Lantana. The shading intensity of restoration arrows indicates the intensity of effort required to ameliorate stressors or reverse changes in ecosystem processes that affect underlying conditions of plant growth in the forest of Corbett tiger reserve

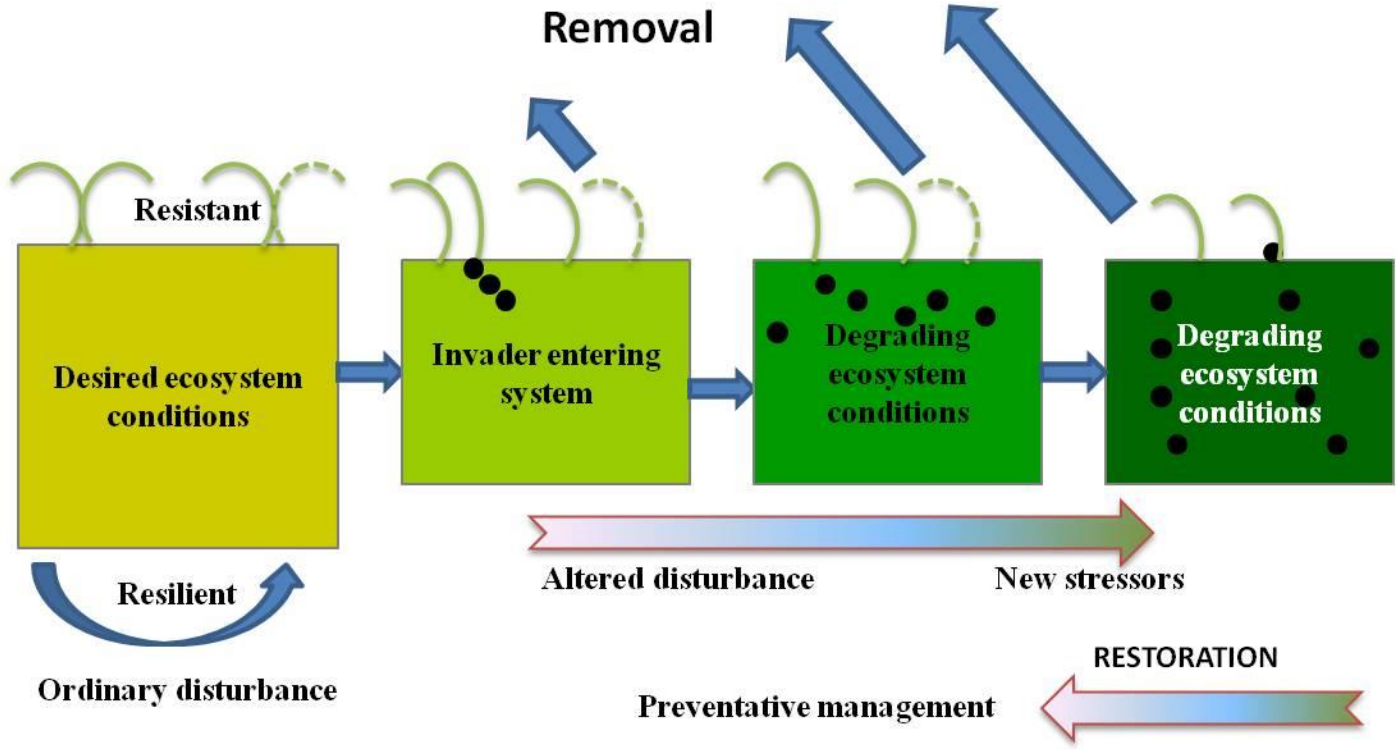

Fig.4. Conceptual Scheme Analysis by forest depart For Restoration of Systems Affected By Invasive Plant Species in Corbett Tiger Reserve. Source: restore ecosystems affected by invasive plant species by Carla M.D'Antino and Jeanne C.Chambers

3. TRADITIONAL METHODS USED FOR CONTROL OF LANTANA IN CORBETT TIGER RESERVE:

Mechanical/manual, chemical and biological methods have been used in the control of Lantana. The chemical and biological methods of control are not favored because of environmental and ecological reasons, particularly due to their potential adverse

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effects on other biota present in forest ecosystems, and hence not practiced by the managers of protected areas in India. Burning of Lantana clumps coupled with the use of herbicides or mechanical removal of Lantana has been used for control of large-scale infestations of Lantana. The most common methods used in Corbett Tiger Reserve, India for the control of Lantana in forests are: (i) hand pulling, (ii) slashing/chopping of the stems, (iii) burning and (iv) manual grubbing with substantial removal of the root system. These methods have had no or little effect in controlling the spread of Lantana infestation, due to their inherent limitations and absence of an integrated control strategy. Table 1 gives limitations of different control methods used for Lantana infestation in forest ecosystems, particularly in protected areas. Some of these methods such as slashing/chopping and burning of Lantana clumps have actually led to the further worsening of the infestation; and in some areas, burning of the weed has promoted its spread to new areas. In other words, management of Lantana has become a vicious circle in which the control activity and reappearance and the spread of new infestation of Lantana are inextricably linked though inadvertently.

Fig. 5. Traditional Methods practiced for the control of Lantana in forest ecosystem development team in India and their limitations

Source: Author

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4. BIOLOGY OF THE INVASIVE WEEDS LANTANA CAMARA

a) Description Of Lantana: Lantana camara is a heavily branched shrub that can grow in compact clumps, dense thickets or as a climbing vine. The stems are square in cross section, with small, recurved prickles. Most leaves are about 6 cm long and are covered in fine hairs. They are bright green above, paler beneath and have round-toothed edges. Leaves grow opposite one another along the stem. When crushed the leaves produce a distinctive odour. Flowers appear throughout most of the year in clustered, compact heads about 2.5 cm in diameter. Flower colours vary from pale cream to yellow, white, pink, orange and red. Lantana produces round, berry-like fruit that turn from glossy green to purplish-black when ripe.

b) Life Cycle Of Lantana: Flowering and germination occurs all year round but peaks after summer rains. Several thousand seeds can be produced per square meter and these can remain viable for several years. They also produce some viable pollen and have the potential to cross-pollinate with wild forms, creating new varieties that could naturalize in the environment. If the numbers of naturalized varieties increase due to genetic drift from ornamental varieties, it will make finding effective biological control agents even more difficult and potentially extend the climatic tolerances and range of the weed's spread.

c) Methods Of Spread Of Lantana: Spread mostly through the garden ornamental trade, by fruit eating birds and mammals. Lantana camara can also spread via a process known as layering, where horizontal stems take root when they are in contact with moist soil. It will also reshoot from the base of vertical stems.

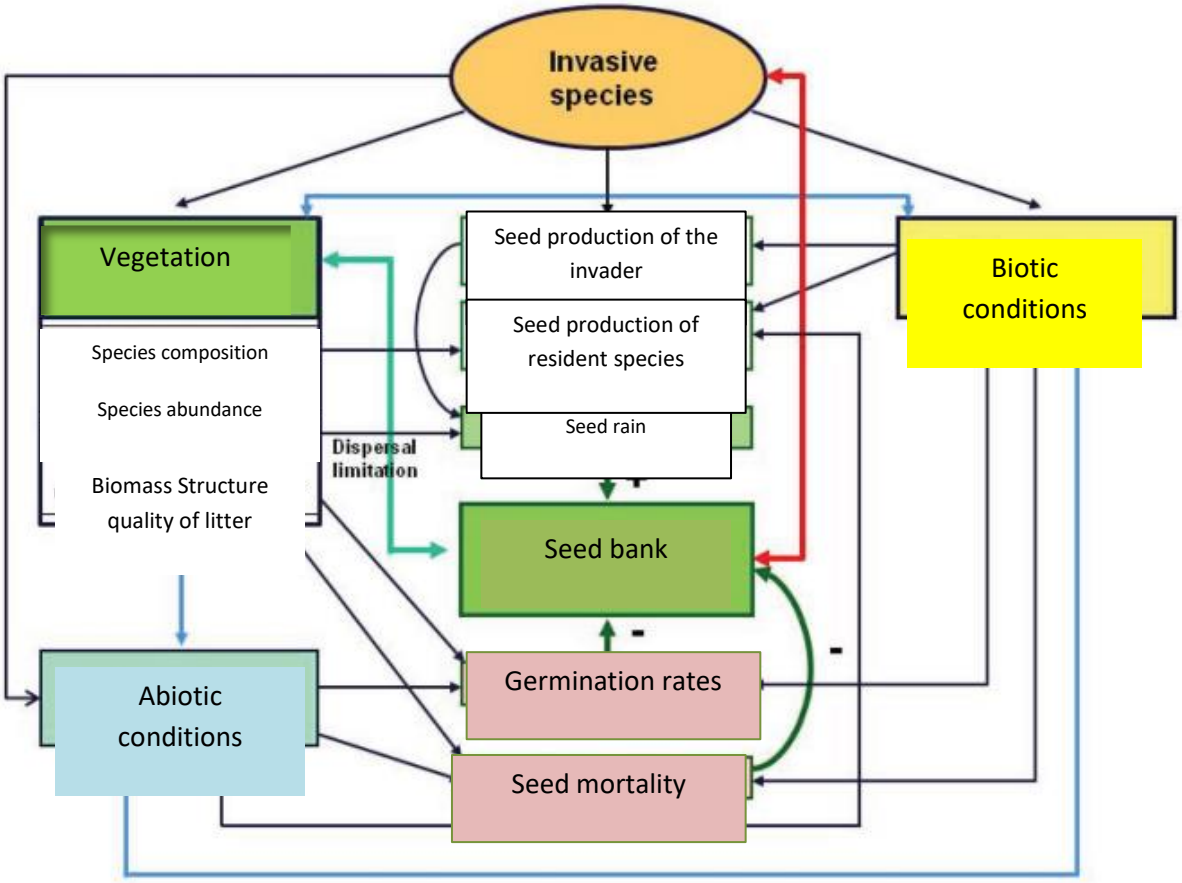

Fig.6 The introduction of invasive alien plant species may affect the soil seed bank directly, via the production of viable seeds; indirectly, via changes in the aboveground vegetation; in other biotic conditions, including the abundance and identity of natural enemies and pollinators; and in abiotic conditions Source: Gioria et al. 2012

d) Ecological Linkages Between Aboveground And Belowground Biota : All terrestrial ecosystems consists of aboveground and below ground components that interact to influence community and ecosystem-level process and properties. Plants (producers) provide both the organic carbon required for the functioning of decomposers subsystem and the resources for obligate root-associated organisms such as root herbivores, pathogens, and symbiotic mutualists. The decomposer subsystem turns breakdown dead plant material and indirectly regulates plant growth and community composition by determining the supply of available soil nutrients. Root-associated organisms and their consumers influence plants directly and also influence the quality, direction and flow of energy and nutrients between plants and decomposers.

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5. NEW MANAGEMENT STRATEGY FOR THE REMOVAL OF LANTANA AND RESTORATION OF CORBETT TIGER RESERVE IN INDIA DEVELOPED BY THE RESTORATION TEAM OF FOREST DEPARTMENT:

Substantial work has been carried out on the taxonomy, biology, ecology and management of Lantana. An effective and practical management strategy for the control of Lantana involves addressing issues of (i) invasiveness of Lantana, (ii) invasibility of habitats and (iii) ineffectiveness of the control methods used. Under the Centre of Excellence Programmed of the Ministry of Environment and Forests, Government of India, field biological studies on Lantana were carried out for eradication of Lantana in forest ecosystems. The objectives of the new strategy are: (i) control of Lantana infestation in already invaded areas and (ii) to contain the spread of Lantana to new areas.

Component 1: Conceptual And Implementation Planning : Sites for removal of Lantana are identified through field surveys ,using the data collected on infestation and density of Lantana. The Lantana removal operation should follow the 'inside-out' method wherein Lantana is removed first from areas with maximum Lantana density and then moving outwards along a decreasing Lantana density gradient. In areas having undulating terrain and hilly tracts Lantana removal operation should be taken up on the slopes first and then downwards to the valley. Planning for the Lantana removal operation should also include the time of removal; the removal operation should be done preferably at a time when a majority of the Lantana clumps are not in flowering or fruiting stage. It may be noted that after removal of Lantana from a site, ecological restoration of weed-free landscape is critical for the control of Lantana. The ecological restoration plan should include the identification of source for selected plant species to be used in restoration, mode of collection of their propagules, development of nurseries for their mass propagation and their subsequent introduction at the site to be restored.

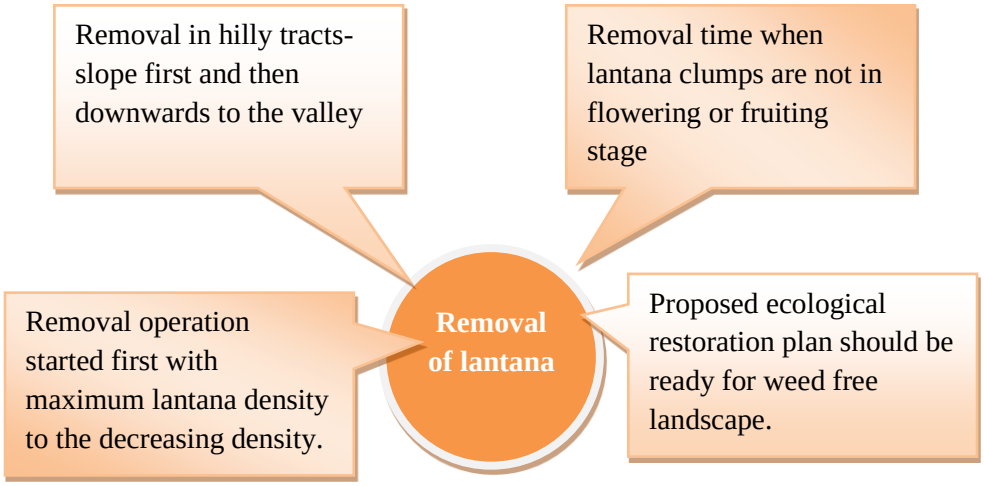

Fig.7 Conceptual and Implementation planning for removal of lantana in Corbett tiger reserve Source : Author

Component 2: Removal of adult clumps using cut rootstock method:

One of the innovations in the new management strategy is the development of a simple and cost-effective manual. Method for the removal of Lantana, known as **cut rootstock** method. As the name suggests, it involves cutting the main tap root of Lantana plant beneath the 'coppicing zone' (transition zone between stem base and rootstock) (Figure b). This method of removal involves the engagement of 2–3 individuals to work in a group for the removal of Lantana if the clump is large enough that it cannot be handled by one individual after the rootstock is cut. The steps involved in the cut rootstock method are: Figure.9 (i) The person, who engages in removal of Lantana, is positioned in a way that he stands near centre of the Lantana clump with his back facing the clump and holding the handle of digger (kudal) (Figure c). (ii) Using the specially designed digger, the person cuts the main rootstock of Lantana 3–5 cm below the soil surface by

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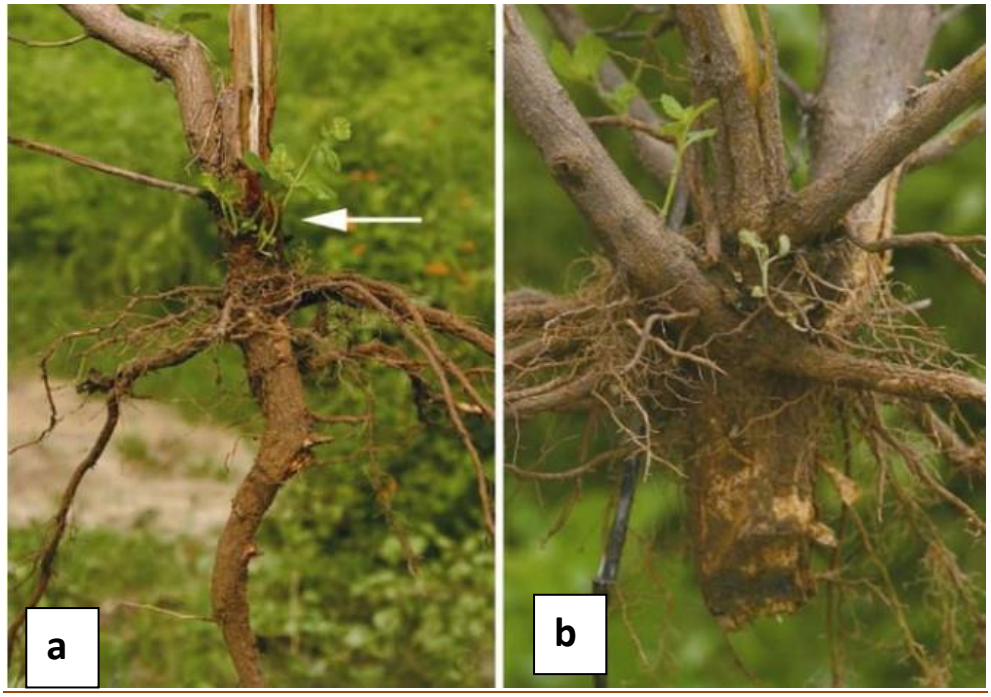

Figure 8. a, Uprooted Lantana Plant Showing Coppicing Zone At The Transition Between Stem Base And Root. b, Lantana Removed By Cutting The Rootstock Below The Coppicing Zone.(SOURCE DEC 2009 ECOLOGICAL RESTORATION 27:4)

the main rootstock of Lantana 3–5 cm below the soil surface by hitting the rootstock 3 or 4 times (Figure d); (ii) Using the specially designed digger, the person cuts the main rootstock of Lantana 3–5 cm below the soil surface by hitting the rootstock 3 or 4 times (Figure d); while hitting the rootstock the blade of the digger gets lodged into the main tap root, and at this point it is useful to move the handle of the digger in the forward direction away from the body of the person so as to severe the connection of the clump with the main tap root (Figure e). In case the clumps of Lantana form impenetrable thickets, it is advantageous to cut the rootstocks of 3–4 contiguous clumps to make the removal operation convenient.. The branches of Lantana thicket formed by more than one clump should be lifted and tipped over from one end by using a wooden or bamboo pole of about 1.5–2.5 m long and diameter 5–6 cm which is inserted just below the branches from one side and rolled over easily by two workers holding the pole at either end and pressing it so as to reach the centre of the clump (Figure 2 a and b). Such manual handling of impenetrable thicket is possible because of the umbrella type of canopy which makes it difficult to reach the centre of clump easily. Such physical maneuvers minimize or prevent regeneration from rooted cut branches when they fall on the ground. (iii) Lift the clump/s and place the clump/s upside down (Figure 2 f and g). If the clump is not placed upside down, the prostrate rooted branches and the aerial old branches having aerial roots at nodes may develop into adult plants when
they come in contact with the soil. Therefore, the upside– down orientation of cut clumps is critical in the prevention of regeneration of Lantana from cut clumps. (iv) After drying the clumps, the clumps may be used as fuel or burnt at the same site or all the dried clumps may be collected at one place and then burnt.

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Figure 9. Sequential Steps (a–g) Involved In The Removal Of Lantana By Cut Rootstock Method (source : current science, vol. 97, no. 10, 25 november 2009.)

Component 3: Weeding out of seedlings/young plantlets of Lantana: A systematic search for trees used by the generalist bird species for perching needs to be carried out after Lantana's removal, both from areas where Lantana is removed and its neighboring areas extending up to a radius of 1 km, vulnerability of the area. Habitats subjected to anthropogenic disturbances such as fire are more prone to invasion by Lantana. These habitats include habitat edges or ecotones (forest and grassland edge) and abandoned agricultural fields after resettlement of villages from forest areas. After location of the trees used for perching by birds in these habitats, all the saplings found beneath them and along the surface run-off channels originating from the areas covered by them, should be removed manually and burned. Continuous surveillance of the areas, where Lantana clumps have been removed and the areas beneath trees used for perching by birds from where the saplings are removed, is necessary consecutively for three growing seasons(monsoons) for the emergence of new saplings.

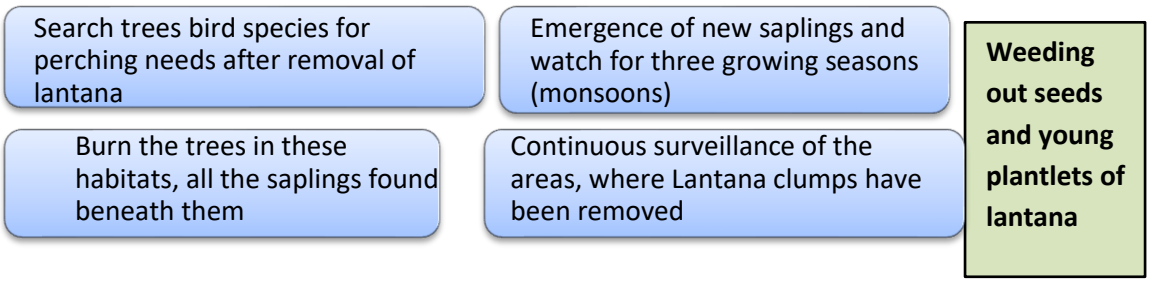

Figure 10.Process Of Weeding Out Planets And Seeds Source : Author

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Component 4: Ecological restoration of weed-free landscapes If the weed-free landscapes are not ecologically restored, reinvasion by Lantana or secondary invasion by some other alien/native weeds such as Parthenium, Cassia tora, C. occidentalis and Sida takes place. Therefore, ecological restoration is critical in the management of Lantana in the forest ecosystems. Weed-free landscapes in open areas can be easily restored to grassland communities by planting rooted ramets or clumps of native grass species or by broadcasting pellets containing seeds of grass species. If the weed-free landscape has to be developed into a forest ecosystem, the native bottom–up woody species that process the habitat can be planted along with grass species or can be introduced in a sequential manner. Ecological restoration should be carried out concurrently with removal of Lantana without much of time lag. The species assemblages of grasses and legumes used for ecological restoration vary across the ecological gradients, and thus the species of grasses and legumes selected for restoration are site-, locality- and region-specific

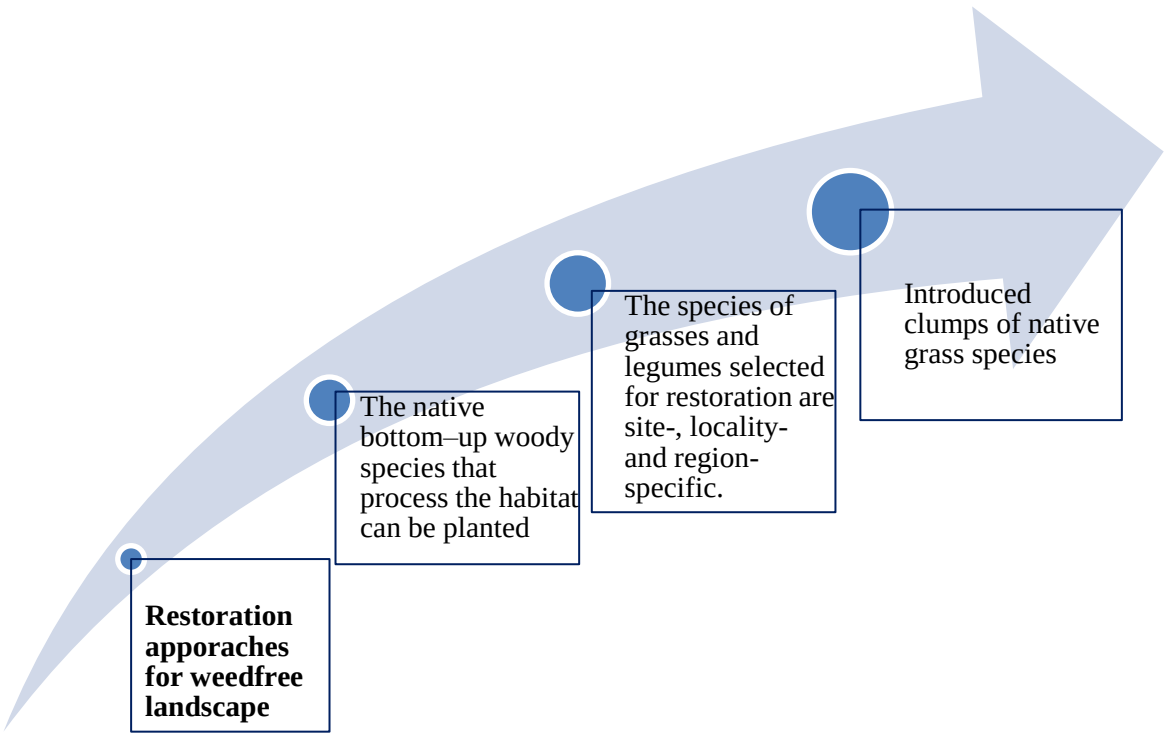

Figure 11. Restoration approaches after Weed-free landscape Source: Author

6. IMPLICATIONS OF PLANT FORM AND SOIL SEED BANK OF LANTANA ON ITS MANAGEMENT:

It is noted that Lantana has a characteristic root system with a main taproot that penetrates vertically up to a depth of 1 m and with lateral roots that grow horizontally up to 5 m in the top 6 cm soil horizon. Such root architecture makes it easier for pulling the clump after cutting the taproot beneath the coppicing zone, i.e. at 3–5 cm depth of soil without much disturbance of the soil. In cut rootstock method the disturbance of soil is minimal, and therefore least number of scarified seeds from the soil seed bank are exposed to light resulting in sprouting of few seedlings of Lantana at the site from where mother clumps are removed. The cut rootstock method developed by us is the outcome of our understanding of the biology and ecology of Lantana and the reasons for the failure of established control methods. The advantages of the cut rootstock method over other methods are: (i) less labor intensive, (ii) practically no regeneration from the cut Lantana clumps, (iii) minimum disturbance of the soil, (iv) reduced germination of Lantana seeds on the eradicated site near the mother clumps, and (v) cost effectiveness, depending upon the intensity of Lantana invasion and topography of the area). These observations were based on the analyses of the sites where physical grubbing and cut rootstock methods were used for the removal of Lantana in forest areas of Corbett tiger reserve.

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The advantages of the cut rootstock method over traditional methods developed by the restoration team of forest department of India

Practically no regeneration from the cut Lantana clumps	Minimum disturbance of the soil	Reduced germination of Lantana seeds on the eradicated site near the mother clumps	Less labor intensive	Cost effectiveness

Figure 12: The advantages of the cut rootstock method over traditional methods in forest areas of Corbett tiger reserve, India Source: Author

7. DISPERSAL AND GERMINATION OF SEEDS AND NEW MANAGEMENT STRATEGY:

One of the important aspects in the management of Lantana invasion is the prevention of spread, reinvasion and secondary invasions by other weedy aliens in areas from where Lantana is removed. The fruits fallen beneath and around the mother clump do not germinate immediately because of the boney endocarp around the seed; only after natural scarification of boney endocarp by microbial degradation and subsequent exposure to light, the seeds germinate. Some old buried seeds brought to the surface through the activities of soil animals may germinate. On the other hand, the seeds defecated by fruit foraging birds/herbivores germinate whenever sufficient moisture is available, as boney endocarp is scarified as it passes through the digestive tracts of frugivores. Some of the defecated seeds are carried by monsoon water and deposited all along the surface drainage channels and along riverbeds. In Corbett Tiger Reserve Gardinia turgida and Zizyphus maurtiana are the most common perching trees. It is that observed 500 saplings of Lantana under a single tree of G. turgid. It may be noted that the timing of removal of Lantana in India should be before the onset of 'seasonal rains' to avoid the flowering and fruiting of a number of Lantana clumps. Otherwise, these clumps will set fruit and provide seed material which can be dispersed by birds and other animal dispersal agents over a large area to start new invasions after monsoon. Seed production has to be virtually eliminated, if a weed has to be eradicated successfully. Seeds of Lantana remain viable for many years and can contribute to nearly 50–70% to the total soil seed bank where Lantana is present. One of the major reasons for recolonization of weed-free areas is that the seeds of Lantana remain viable in soil for a long time and sprouting of Lantana seeds takes place whenever the seed is exposed to light. The sprouting of Lantana seeds and their establishment can be further prevented by restoration of the weed-free landscapes
to grassland communities.

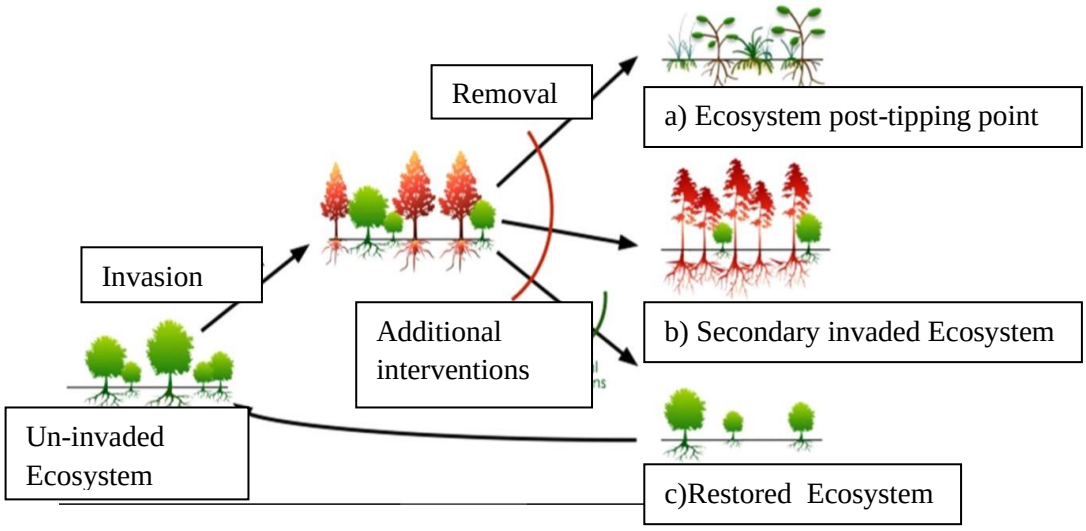

Fig.13 Three trajectories for removal of invasion for forest ecosystems.

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a) Return to original community. Requires modification of habitat, reintroduction of native species. **b)** Persistence of legacy of the removed invader through secondary invader or by other invasive species. C) Movement of past tipping point that prevents the ecosystem both from original ecosystem and pre-invasive system. .These can be applicable to invasive belowground consumers and aboveground consumers to transform the ecosystem. Source: Forest Invasions David A. Wardle Duane A.Petlzer, Springer

8. Positive Outcome / Results: Using the new management strategy outlined here, Lantana has been successfully removed from the three plots of varying size (2–5 hectares) in Corbett Tiger Reserve and the weed-free areas have been restored into luxuriant grasslands. After three years, the newly developed grasslands are visited by large herds of deer, along with wild boars and elephants. The frequency of wildlife sighting has also increased in these plots. Several grassland birds have been using these restored habitats for foraging and nesting. Following the strategy developed, the Management of Corbett Tiger Reserve has successfully removed Lantana from 1600 hectares and restored the weed-free landscapes toGrasslands. The Forest Department of Uttarakhand has undertaken eradication of Lantana on a massive scale using the new management strategy**.** Keeping in view, the fact that the national parks and wildlife sanctuaries are repositories of biological heritage and that the invasive species such as Lantana threatening the very biological heritage for which the protected areas were established, ensuring the conservation of biodiversity in forest ecosystems.

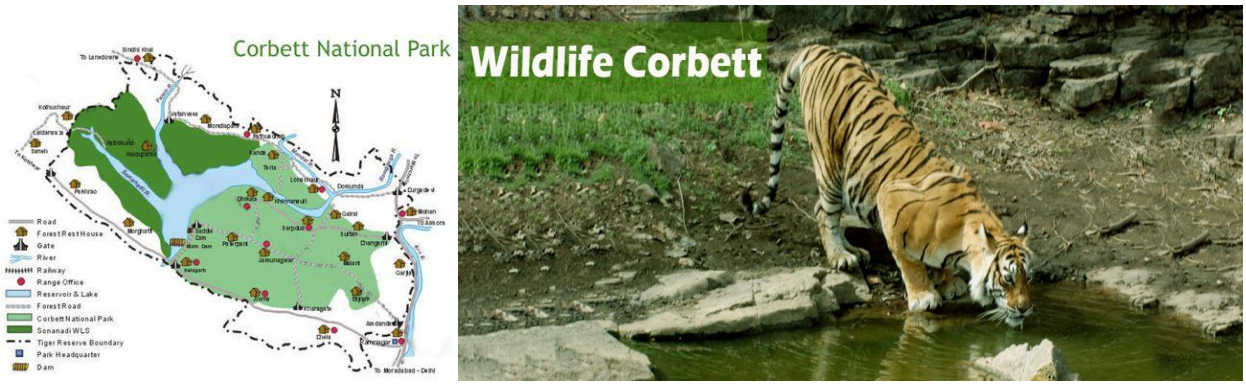

Fig.14 Map Of Corbett National Park And The Return Of Fauna After Restoration.(source www.jimcorbett .in)

9. CONCLUSION

This is a Review Paper, Studied and Analyzed from the existing presented papers and reported the Topic. Choose the ecosystem type as forest ecosystem-Forest invasions. The case investigation– forest invasions- Corbett tiger reserve of India (Uttarakhand).

Lantana has become a menace in forest ecosystems and is distributed across the tropical and subtropical India. A wide range of physical control measures have been followed in the management of Lantana weed, but without success. The failure of the physical methods used is due to certain biological and ecological attributes of the weed that made the methods of control ineffective, and enabled the weed to invade rapidly far and wide through dispersal of seeds by mutualistic frugivorous birds. The new cut rootstock method coupled with weeding of saplings under the trees used for perching by generalist birds and subsequent restoration of weed-free landscapes to grassland/ forest community can eradicate Lantana successfully. Understanding of the natural histories of other invasive weeds will enable to evolve effective and efficient management strategies for their containment in the forest ecosystems.

1. The information on dispersal process, life-history, controls and population of invaders facilitate to control the invasions should be collected.
2. Information On effects of invaders on ecosystem processes can contribute more understanding of disturbed conditions.
3. Information on the pathways which both natural and anthropogenic disturbances including restoration management activities, study of individual species, native, non-native helps to identify the ways of disturbance and suggest pathway to restoration.
4. Information on phenology (the study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life) of growth and resource uptake of species ecosystem could be used as a tool of restoration.
5. The ability to use preventive management or restoration effectively to maintain ecosystems that are both resistant to invaders and resilient to disturbances will depend on the characteristics of the ecosystem interest as well as those of the invaders.

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