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Geospatial mapping of ecoraces of tasar silkworm (*Antheraea mylitta* Drury) using remote sensing and geographic information system techniques

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ABSTRACT

Tropical Tasar silkworm *Antheraea mylitta* Drury (Family: Saturniidae) produces Tasar silk which has very high demand globally and because of their wide range of distribution in tropical regions, they have adapted to different niches forming different ecoraces. In Odisha, alone seven types of ecoraces of *A. mylitta* have been reported, namely Modal, Sukinda, Nalia, Jata-Daba, Adaba, Umerkote, and Boudh. These ecoraces show differences in their phenotypes, genetic constitution, fecundity, voltinism, etc. In the past few decades, there is the substantial deterioration of habitats due to many anthropogenic activities. This has resulted in a large decline in wild Tasar cocoon production. Lepidopterans are accepted as ecological indicators of ecosystem health and it is apprehended that through anthropogenic and climatic factors this precious genetic resource, which took millions of years to evolve, may face the threat of extinction shortly if adequate conservation measures are not taken. This paper attempts the geospatial mapping of these ecoraces in the state of Odisha through RS and GIS tools, which will provide a greater scenario for their conservation.

Introduction

The Tasar (tussah/tussor/tussore) silkworm is a semi-domesticated wild silkworm that belongs to the family Saturniidae. Almost 35 species of *Antheraea* are responsible for the production of wild silk. Out of those 35 species, 3 species are exploited in India for wild silk culture, i.e. Tropical Tasar silkworm (*A. mylitta*), Temperate Tasar silkworm (*A. proylei*), and Muga silkworm *(A. assama)* (Jolly, 1985). The *A.mylitta* wild distribution is spread over West Bengal, Odisha, Andhra Pradesh, Jharkhand, Bihar, Chhattisgarh, Madhya Pradesh, and Maharashtra states of India (Sinha, 2003). Observations indicated that the distribution of *A. mylitta* Drury is almost between 12-31°N latitude and 72-96°E longitude. To date almost 64 ecoraces have been reported (Rao *et al.* 2003). In the state of Odisha total number of 7 ecoraces have been reported, namely Modal, Sukinda, Nalia, Jata-Daba, Adaba, Omarkote, and Boadh/Boudh (Table-1). These ecoraces are mainly restricted to tropical moist deciduous forest areas (Sinha and Prasad, 2011). Geospatial technology includes GIS (Geographical Information System), GPS (Global Positioning System), and satellite-based technologies such as RS (Remote sensing). GIS mostly captures image data, its input, update, transformation, manipulation, query, modeling, analysis, and visualisation of geographically referenced information through a set of computer programs (Bonham Carter, 2014). GPS provides positioning, navigation, and timing (PNT) services by capturing data from satellites (Eldredge *et al.* 2010). RS is an earth observation instrument that delivers regional information on climatic factors and landscape features (Saran *et al.,* 2020). For regional and spatial information, GPS and RS are useful. But for geospatial data integration as well as accurate geospatial analysis in a real-time manner,

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Table 1: Ecoraces found in Odisha and their preferred host plant (Vijayan *et al.*, 2010)

SN	ECORACE	PREDOMINANT FOOD TYPE	SOIL TYPE	FOREST TYPE
01	Modal	*Shorea robusta*	Red Loamy	Tropical moist deciduous
02	Sukinda	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
03	Jata-Daba	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
04	Umerkote	*Shorea robusta*	Red Loamy	Tropical moist deciduous
05	Boudh	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
06	Adaba	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
07	Nalia	*Shorea robusta*	Red Loamy	Tropical moist deciduous

GIS has been proven very useful (Zhen *et al.,* 2010). In order to preserve the natural biodiversity present in the *Antheraea mylitta* species population, attempts are made to understand and conserve their ecoraces. These ecoraces conservation (in-situ and ex-situ) links genetic diversity to utilisation, protecting diverse gene pools, habitats, and ecosystems for human socio-economic needs (Metzler and Zebold, 1995). Through their ecorace conservation, we can utilise their valuable genes in enhancing productivity (Mirhosein *et al.,* 2004) and building their new population through the genetic hybridisation technique (Kumaresan *et al.,* 2004). The increasing international demand for Tasar silk, their abundance of host plants, and the limited option of productivity of ecoraces for commercial rearing demand the exploration of these ecoraces (Ojha *et al.,* 2009). Previously, Sinha and Prasad (2011) mapped the distribution of all 44 ecoraces of *A. mylitta*. Sahay *et al.* (2011), have identified the Tasar culture growing regions of Odisha. Renuka and Shamitha (2015) have also mapped the location of Daba, Bhandara, Andhra local, Modal, Sukinda, and Railey ecoraces in India. But there is no particular map available for all the ecorace found in Odisha yet. Hence the need for a map showing the location of different ecoraces in Odisha is a must for further development of sericulture in the state. In this current paper, an attempt has been made to map all the available ecoraces of Tasar silkworm (i.e. Modal, Sukinda, Jata-daba, Omarkote, Boudh, Adaba, and Nalia) and their geographical locations in different regions of Odisha (Table 2).

Material and Methods

Study area:

Odisha is a state of Eastern coastal India, situated between latitude 17°78'N and 22°73'N and longitude 81°37'E and 87°53'E, covering an area of 1,55,707km^2, which is 4.87% of the total area of India, with a coastline of 450 km. According to the 2021 forest cover estimation published by Odisha State Forest Department (https://www.odishaforest.in), the total forest cover of Odisha is almost 61,204km^2, which makes up 39.31% of the total land of the state. Out of 30 districts of Odisha, most of the ecoraces of Tasar silkworm *A. mylitta* are confined to Mayurbhanj, Boudh, Gajapati, Jajpur, Kalahandi, Nawarangpur, and Sundergarh districts.

Non spatial data collection:

For individual location identification of different ecoraces and their cultivation grounds, both primary and secondary data have been used. Secondary data have been derived from different research papers available about ecoraces and their endemic locations from different authors. For Modal, Nalia, Sukinda, and Jata-Daba both primary and secondary data have been utilised. For Boudh, Umerkote, and Adaba, only primary data have been collected from forest personnel of those regions and regional TRCS (Tasar Rearers Cooperative Societies) centers.

Map plotting:

The mapping has been done with intensive use of Geo-information technology like RS (Remote Sensing), and GIS (Geo Information Systems) (Fig-1).The source political map of Odisha with its 30 districts has been obtained from https://gisodisha.nic.in. The Forest boundary map of Odisha was collected from official website of the Odisha state forest Department (https://www.odisha forest.in). The forest map data belongs to the 2021 official data record issued by the government of Odisha, mapped with IRS-Resourcesat 2- LIS III, with a spatial resolution of23.5m and a scale of 1:50,000. For the protected areas and their spatial data collection the official boundary map of different sanctuaries and national parks has been obtained from the Forest and Environment Department of Odisha http://odishawildlife.org/map.html. Shapefiles of

Table 2: Ecoraces and their geographical distribution in Odisha

Ecorace Name	Location Name	Location On Map	Average Elevation Asl (In Meters)	District
MODAL	Gudgudia	21°52'59"N 86°15'19"E	379	Mayurbhanj (Similpal National Forest)
	Sarat	21°26'39"N 86°20'38"E	203	Mayurbhanj (Similpal National Forest)
	Lulung	21°56'42"N 86°33'20"E	300	Mayurbhanj (Similpal National Forest)
	Arjunvilla Village	22°06'14"N 86°15'24"E	335	Mayurbhanj (Similpal National Forest)
	Khadambeda	22°10'55"N 86°25'34"E	358	Mayurbhanj (Similpal National Forest)
	Kitabeda	22°10'07"N 86°25'16"E	350	Mayurbhanj (Similpal National Forest)
SUKINDA	2.1 Ankurpali	22°19'21"N 84°53'36"E	242	Jajpur
	2.2 Sukaran	20°57'30"N 85°57'57"E	223	Jajpur
	2.3 Kundal	20°39'52"N 86°10'28"E	72	Jajpur
	2.4 Kansa	21°91'54"N 85°56'53"E	63	Jajpur
NALIA	3. Raghubeda Forest Range	21°28'52"N 85°46'33"E	434	Keonjhar
JATA-DABA	4.1 Thakurmunda	21°31'24"N 86°09'39"E	329	Mayurbhanj
	4.2 Kendujuiani	21°39'03"N 86°07'03"E	346	Mayurbhanj
	4.3 Mahuldiha	21°26'55"N 86°10'39"E	268	Mayurbhanj
	4.4 Kuldiha	21°27'04"N 86°42'56"E	91	Mayurbhanj
ADABA	5. Adaba	19°40'21"N 84°10'25"E	386	Gajapati
UMERKOTE	6. Umerkote/Umarkote	19°40'21"N 82°12'09"E	612	Nabarangpur
BOUDH	7. Satkosia Range	20°35'12"N 84°27'06"E	320	Boudh

district boundary and forest boundary were converted to KML to find the locations on Google Earth in order to see the present status of the forest in the state. The shape files have been converted to UTM (Universal Transverse Mercator) to calculate areas of cultivation ground and for correct placements of scale bones. The next step was to pin mark different villages of Tasar silkworm Ecoraces. For this purpose individual village or area location was pinned using Google Earth-9 software. The GIS of google earth is supported by Google Landsat 8 with Copernicus sentinel (Data SIO, NOAA, U.S. Navy, NGA, GEBCO). For individual precise pinning of different villages that are located within 60 km^2 of area of each other, Maxar technologies, CNES/Airbus and Terrametrics source help of same Google Earth-9 software has been taken. The project file of pinned locations with georeferences of ecorace clusters in different districts of Odisha that has been done with Google Earth 9 software. The forest cover map and pinned location map have been overlaid together to create a new more informative map of our interest cultivation grounds, nearby forest covers, along with to which district or range the villages belong to can be shown together in a single map image. Area calculation of different cultivation ground or forest ranges in different districts has been done through ISRO- CHAMAN

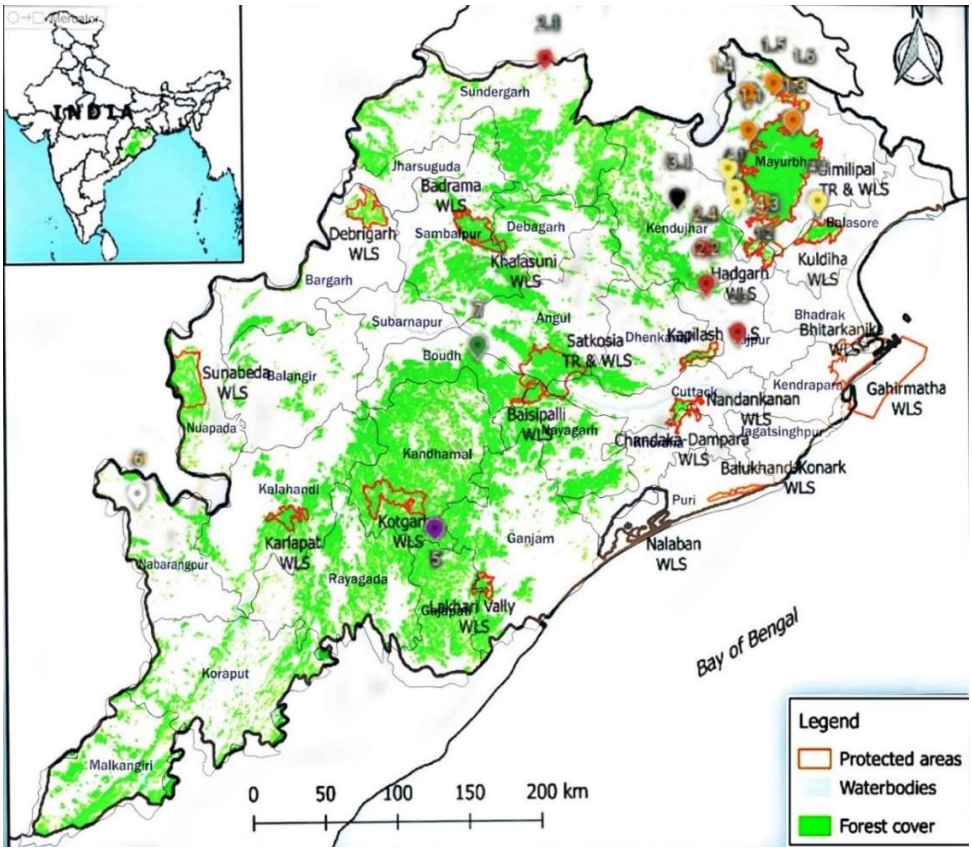

Figure 1: Location mapping of different ecoraces of Tasar silkworm *A.mylitta*

(Coordinated Programme on Horticulture Assessment and Management using Geoinformatics) and Bhuvan-2D and Bhuvan-3D websites. After this appropriate band combination, necessary contrast enhancement has applied to make the image more interpretable.

Results and Discussion

The 7 ecoraces of Tasar silkworm *Antheraea mylitta* found in Odisha are Modal, Sukinda, Nalia, Jata-Daba, Boudh, Omerkote, Adaba.

Modal: The modal ecorace is endemic to the Similpal National Park and Biosphere Reserve and to nearby regions of Mayurbhanj. It is one of the largest and highest-yielding Tasar ecorace. This ecorace is exclusively wild, univoltine, almost disease free, and produces the heaviest cocoons. This ecorace alone contributes to 19% of raw silk production in India and this area of almost 823sq.km is covered by semi-deciduous forest. The Similpal National Park is spread over an area of 2750sq.km area out of which the core region is 303sq.km area (Sahu and Debta, 2020). The abundance of Arjun, Asan, and Sal plants in the forest region is responsible for the good habitat of the Modal Tasar silkworms.

Sukinda: The trivoltine Sukinda ecorace is economically profiting for the sericulture. State Department of Sericulture collected this ecorace from the Kundal, Ankurapa, Sukaran, and Kans areas of Sukindagarh of Jajpur district, in the 1970s and then introduced them to other regions for cultivation (Sahay *et al.,* 2011). For our mapping purpose, these regions have been selected. The cocoons are yellow or grey in colour, having a silk ratio varying between 10.5-13.1%. This race particularly is semi-domesticated and they perform better in semi-domesticated environments than in wild. Sukindagarh used to be the main hub for

Sukinda ecorace cultivation but since this region is full of ore mines and industries, which are constantly being over exploited, the negative impact of this over-exploitation, mining, and industrialisation are affecting the natural habitat of Sukinda tasar ecorace.

Nalia: A bivoltine ecorace of *A. mylitta* found in near forest area of the Keonjhar district of Odisha. Early multiplication, short larval period, and better quality commercial character make this ecorace more desirable by Sericulturist (Rout *et al.,* 2009). The availability of this ecorace is in the range of Raghubeda Forest range of Keonjhar and the forest patch between the borders of Sundergarh and Keonjhar district of Odisha.

Jata-Daba: Another bivoltine ecorace of *A. mylitta* is found in almost 35 villages of the Thakurmuda region of Mayurbhanj (Rout *et al.,* 2008). For our mapping purpose, we have taken Thakurmuda, Kendujiani, Mahuldiha, and Kuldiha of the Mayurbhanj district. This ecorace is preferable because of its higher percentage silk content.

Adaba: Adaba ecorace is one of the most unexplored ecoraces of Odisha found in the Adaba forest Gajapati district. Since Adaba is also one of the wild ecoraces, almost all of its life stages are spent in the wild on its host plant. The Naxal issues in the Adaba forest have always been a greater hindrance to the biological exploration of local fauna and flora including its endemic Tasar silkworm ecorace and its host plant. This is the same reason why the Adaba ecorace is unknown to many sericulturists and researchers of this field.

Umerkote: Umerkote/Omarkote is one of the endemic ecoraces found in Kalahandi and Nawarangpur forest cover regions of Odisha. The forest area is mostly covered with moist deciduous forest of 298km^2.

Boudh: Although not many reports have been published about this ecorace, but some papers do claim that this Boudh/Boadh Ecorace is also found in the Phulbani region i.e. new Boudh and Kalahandi district (Sinha and Prasad, 2011). This ecorace is suspected to be endemic to the moist deciduous forest range of these two districts and some parts of nearby regions. Sinha and Prasad (2011), have proven that the morphological difference between different ecoraces is relevant to their biochemical constitutions like protein content, lipid content, and carbohydrate content, including genetic constitutions, which makes each ecorace genetically unique from their sister ecorace. It also has been noticed by them that the *Shorea*-based ecoraces (Modal, Nalia, Umerkote) have greater shell weight as compared to *Terminalia*-based ecoraces like (Sukinda, Boudh, Jata-Daba, Adaba). In some research papers, Bogei is also considered as a separate ecorace of *A. mylitta*, but in reality, it's the rearing (commercial) variety of Modal and Nalia that are called Bogei by local people.

The evolution of GIS, GPS, and RS technologies has enabled the collection and analysis of spatial, non-spatial, and field data in such a sophisticated manner that was not possible before the arrival of these software technologies. The use of these technologies in India increased after the 1990s IT revolution. Since the 2000s these technologies have been actively in use by both Government and Non-government authorities worldwide for Resource management such as agriculture, soil, water, land cover, forest cover estimation, mining area detection, Wildlife management, and agricultural land detection, etc. Currently, the advancement of mobile technology also has enabled to use the GPS via satellite imaging for regular use without any expensive handset use. In 2011, Sinha and Prasad mapped all the 44 ecoraces of *A. mylitta* Drury documented officially, using imagery techniques of GIS data. The horizontal accuracy within a map depend mostly on the Ground Sampling Distance or GSD i.e., number of pixels per centimetre. Inaccurate maps will lead the investigator astray because the critical data point of the problem might not be there at the moment on the Map. Hence accuracy of the map is very critical for right investigation of the project. In India ISRO Bhuvan (2014) and ISRO-CHAMAN (2014) are in use for the estimation of area of land forest cover, coast line, and Plantation cover, etc. CHAMAN GIS is exclusively used for agricultural, horticultural and forest assessment. Banana, Citrus fruit, and Mango plantation cover of different states is already in the data base of CHAMAN. Similarly, we can implement the GIS and GPS along with data from Imagery RS to create locational plantation planning for A. mylitta Drury host plants such as Arjun, Asan, and Sal in corresponding regions where the availability of different ecorace prevails. By doing

so, more host plants will be available for Tasar silkworm culture to the local tribe people which in turn will improve the economy of the region.

Conclusion

The potential use of RS and GIS has been very satisfactory for the study of forest cover and locations in required places. RS, GIS, and GPS techniques have been very crucial in our field for geospatial mapping of Tasar silkworm (*A. mylitta*) ecoraces throughout Odisha. As for spatial data collection, there is still a lot of knowledge gap among professionals regarding the availability of ecoraces and their geographical distribution. The LANDSAT 9 images have been very useful for the identification of individual villages and nearby forest range. In Odisha, mostly Modal, Sukinda, and Nalia are commercially exploited for Tasar production. Other Jata-Daba, Umerkote, Boudh, and Adaba don't have that much commercial importance yet because they yet have to be explored properly in their endemic places. Geospatial mapping technique has long been in our country mapping system. This technique has been used for forest area and forest cover mapping, census mapping, cluster mapping of plantations, coastal erosion checking, etc. Many states including Odisha have been collaborating with ISRO (Indian Space Research Organisation) for all GIS, GPS, and RS data for different censuses like tiger reserves, elephant reserves, etc. But for Tasar silkworm (*Antheraea mylitta* Drury) ecoraces and their mapping, no organised map have ever been in the picture. Hence to fulfil such a demand for the growth of the economic status of Tasar silk production and available ecorace genetic pool diversity maintenance, the Geospatial technique of mapping might be proven a greater success.

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Conflict of interest

The authors declare that they have no conflict of interest.

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