ISSN : 0975 - 9425

INDIAN JOURNAL OF ENVIRONMENTAL EDUCATION

VOLUME 20, APRIL 2020

C.P.R. ENVIRONMENTAL EDUCATION CENTRE

The C.P. Ramaswami Aiyar Foundation,

1 Eldams Road, Alwarpet, Chennai - 600018.

Indian Journal for Environmental Education is a peer-reviewed publication

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Indian Journal of Environmental Education is published annually by

C.P.R. ENVIRONMENTAL EDUCATION CENTRE
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Editor's Note

In view of the extraordinary situation caused by the Covid - 19 pandemic, we have been constrained to publish the Indian Journal of Environmental Education (IJEE) much later than usual. This has been unavoidable due to the limitations of staff and even printers.

I would like to thank all the contributors, who have put in their best effort to give us very useful and interesting articles in spite of closed libraries and practically no mobility due to the lockdown.

Finally, my sincere thanks go to the staff of CPR Environmental Education Centre (CPREEC) who have come to the office in difficult times and worked hard to put together this issue.

Dr. Nanditha Krishna
Director
C.P.R. Environmental Education Centre

WILDLIFE CRIME DATA INTEGRATION FROM MULTIPLE SOURCES: A WAY FORWARD TO ENSURE PUBLIC ACCESS TO INFORMATION AND DATA ANALYTICS

Shankar Prakash Alagesan*

Abstract

Over a while, the activities of criminals have expanded due to advancements in information and communication technologies. In this background, police and intelligence agencies have been developing a robust crime database in order to anticipate, prevent and monitor criminal activities. Hence, wildlife crime databases become a vital information system that help enforcement officers to detect and prevent wildlife crimes and to pursue wildlife criminals. Therefore, an attempt has been made in this paper to shed light on the available wildlife crime databases in India. Further, an appeal has been made for the integration of wildlife crime data from various sources and make it available in the public domain. This article has also touched upon the importance of data analytics and crime analysts to handle wildlife crime data.

Keywords: Crime Data, Database, Forest, Police, NCRB, WCCB, Wildlife Crime, Crime Analysis

Introduction

Wildlife crime refers to the taking, trading (i.e., supplying, selling or trafficking), importing, exporting, possessing, processing, obtaining, and consumption of wild fauna and flora in contravention of national and international law. Wildlife crime emerged as a significant threat to biodiversity, endangered species, and also to the livelihood of people. These threats, in turn, severely impact the national security, social and economic development of a country (UNODC, 2015). To understand the extent of wildlife crime, a report from the United Nations Environment Programme (UNEP, 2016) estimated that illegal trade in wildlife is up to USD 20 billion per year (approximately INR 2000 crores). By recognising this severe and immediate danger, the international community at large has started to acknowledge the magnitude and significance of wildlife crime. Over-exploitation of wildlife has accelerated its adverse impacts on sustainable development, good governance, the rule of law, and national security (INTERPOL-UN Environment, 2016; McFann & Pires, 2018). The Sustainable

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Development Goals (SDGs), otherwise known as the Global Goals, have also recognised wildlife crime as a menace to environmental protection. Among various targets of SDG 15 (Life on Land) — Targets 15.7 and 15.c, explicitly spelt out wildlife crime and community participation to tackle the same (A/RES/70/1, 2015). The Government of India enacted the Wild Life (Protection) Act, 1972 (hereafter WPA), with the objectives of adequately protecting wildlife through control of poaching, smuggling and illegal trade in wildlife and its derivates. WPA regulated the setting up of three types of protected areas in India, such as wildlife sanctuaries, National Parks, and zoos for the protection of wildlife. Section 50 of the WPA provides officers from the forest department and police department the power of entry, search, arrest, and detention related to wildlife crime. Hunting wild animals or picking, uprooting of specified plants named in various schedules are prohibited under WPA. Also, unauthorised possession, transport and trade of wild animals or plants, and destruction of protected areas/habitat will be punishable. A person who contravenes any provisions of WPA, or any rule thereunder, shall be guilty of an offence against this Act and shall, on conviction, be punishable with imprisonment for a term which may extend up to three years or with fine which may extend to twenty thousand rupees or with both. If the offence committed is concerning with any specified animal, the offender will be punishable with imprisonment not less than one year but may extend to six years and fine shall not be less be than five thousand rupees.

Compliance with and enforcement of any criminal law always needs a datasat.DPKO & OHCHR (2011) have suggested using multiple data sources from the police, judiciary, and correctional institutions to measure compliance and enforcement. Official crime data consisting of incidents reported to and recorded by the police remains a significant indicator to measure police efficiency and effectiveness (*He & Marshall, 1997; Loveday, 2000).* In this background, an attempt has been made in this paper to bring out various sources of wildlife crime data in India and an appeal for the integration of such data to ensure public access to information.

National Crime Records Bureau (NCRB) and Wildlife Crime Data

Over a period of time, activities of criminals have expanded due to advancements in information and communication technology. Harnessing and exchange of relevant information on crime and criminals between various stakeholders become next to impossible as crime and criminal records are maintained manually. At this juncture, the need arises to computerise crime records for the prevention and detection of crime. In 1986, NCRB was set-up under the aegis of the Ministry of Home Affairs, Government of India, as a computerised repository of crime and criminal data (NCRB, n.d.). NCRB publishes crime statistics, namely "*Crime in India*" as an annual publication. Crime data collected from City Crime Records Bureau (CCRB)/District Crime Records Bureau (DCRB) will go to the State Crime Records Bureau (SCRB). SCRB will share the respective state's

crime data annually with the NCRB. NCRB will compile all the data received from various SCRBs to bring out Crime in India statistics. Over the years, crime statistics have become a crucial publication, providing useful and detailed information on crime statistics and trends in India. "*Crime in India*" statistics chaptered in various crime heads such as crime against women and children, juveniles in conflict with the law, economic offences, cybercrimes, and so on. For the first time from the year 2014, environment-related offences added to the crime statistics. The chapter on environment-related offences have current data on the incidence of offences and gender-wise people arrested. Further, police disposal such as (i) total cases investigated; (ii) total cases pending for investigation; (iii) charge sheeting rate and (iv) pendency percentage, etc. and court disposal such as (i) total cases sent for trial; (ii) cases pending for trial; (iii) cases convicted; (iv) conviction rate and (v) pendency percentage, etc. As this paper deals explicitly with the prevalence of wildlife crime in India, this paper will only present the data related to the number of wildlife crime cases registered under WPA.

Table 1 gives an overview of the incidence of wildlife crimes in India for five years (i.e., 2014, 2015, 2016, 2017 and 2018). From Table 1, it is inferred that Uttar Pradesh (UP), Rajasthan (RJ) and Karnataka (KA) topped the list based on the incidence of wildlife crimes. Interestingly, the total number of cases registered in UP and RJ alone constitutes 55 percent of the total (i.e., 4066 cases) wildlife crimes reported all over India. Also, shockingly, in States/ UTs like Meghalaya, Sikkim, Tripura, Dadra & Nagar Haveli, and Daman & Diu, zero cases were reported. Whereas Goa, Manipur, Mizoram, Nagaland, Tamil Nadu, Andaman & Nicobar Islands, Chandigarh, Lakshadweep, and Puducherry have registered cases in single digits by their respective police.

Table 1

State/UT year-wise incidence of wildlife crime in India

Sl. No.	State/UT	Year					Total
		2014	2015	2016	2017	2018	
1.	Andhra Pradesh	9	2	3	3	3	20
2.	Arunachal Pradesh	3	3	1	2	2	11
3.	Assam	73	74	82	49	32	310
4.	Bihar	2	0	7	12	12	33
5.	Chhattisgarh	11	12	15	10	9	57
6.	Goa	2	0	0	0	0	2
7.	Gujarat	36	20	13	3	0	72
8.	Haryana	15	10	9	16	15	65
9.	Himachal Pradesh	15	12	19	18	24	88

10.	Jammu & Kashmir	0	4	4	12	5	25
11.	Jharkhand	0	34	0	2	0	36
12.	Karnataka	84	74	69	58	41	326
13.	Kerala	5	2	8	6	4	25
14.	Madhya Pradesh	15	3	5	10	58	91
15.	Maharashtra	56	20	33	52	47	208
16.	Manipur	0	0	2	1	1	4
17.	Meghalaya	0	0	0	0	0	0
18.	Mizoram	0	1	1	1	1	4
19.	Nagaland	0	0	3	0	0	3
20.	Odisha	1	0	1	3	8	13
21.	Punjab	5	1	2	7	4	19
22.	Rajasthan	219	239	190	208	220	1076
23.	Sikkim	0	0	0	0	0	0
24.	Tamil Nadu	2	2	0	0	0	4
25.	Telangana	3	9	17	1	3	33
26.	Tripura	0	0	0	0	0	0
27.	Uttar Pradesh	149	234	302	264	227	1176
28.	Uttarakhand	6	14	19	21	20	80
29.	West Bengal	45	50	47	59	42	243
Total (States)		756	820	852	818	778	4024
1.	A & N Islands	0	0	0	2	0	2
2.	Chandigarh	1	0	3	2	0	6
3.	D&N Haveli	0	0	0	0	0	0
4.	Daman & Diu	0	0	0	0	0	0
5.	Delhi	12	8	4	4	3	31
6.	Lakshadweep	0	1	0	0	1	2
7.	Puducherry	1	0	0	0	0	1
Total (UTs)		14	9	7	8	4	42
Total (All-India)		**770**	**829**	**859**	**826**	**782**	**4066**

Source: National Crime Records Bureau

Tamil Nadu Forest Department (TNFD) and Wildlife Crime Data

Tamil Nadu has a rich history of forest and wildlife management. The socio-cultural practices of the State have always been an impetus for the conservation and protection of abundant natural resources. Forest and wildlife management are an interdisciplinary approach and practice. Historically, forests in Tamil Nadu were managed by the community living in and around the forest. The first step towards wildlife conservation was initiated with the enactment of the Tamil Nadu Wild Elephants Preservation Act, 1873, which is a century ahead of the enactment of WPA. Soon after the enactment of WPA, to protect wildlife, various places were designated as a protected area (PA) (Tamil Nadu Forest Department, 2016). A protected area is a clearly defined geographical space, recognised,

dedicated, and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values (*Dudley & Stolton, 2008*). PAs in India are designated as National Parks, wildlife sanctuaries, conservation reserves, community reserves and marine protected areas. The PA network in the State covers 7,069.72 km^2, with five National Parks, fifteen wildlife sanctuaries, fifteen bird sanctuaries and two conservation reserves. Some of the PAs are also constituent parts of four tiger reserves — Anamalai, Kalakkad Mundanthurai, Mudumalai and Sathyamangalam. As Tamil Nadu has abundant natural resources, the Tamil Nadu Forest Department aspires to establish an intelligence network to combat wildlife crime and also to establish an electronic database of forest and wildlife offenders (Tamil Nadu Forest Department, 2016). To achieve these aspirations, the collection and storage of wildlife crime data have become a prerequisite.

Since wildlife crime data of Tamil Nadu is not available in the public domain, the researcher has requested the forest department to provide forest division wise wildlife crime data to understand its nature and extent. There is a dedicated wing called Protection, Vigilance & Wildlife Crime Bureau (PV&WCB) with TNFD headed by an officer in the rank of Additional Principal Chief Conservator of Forests (APCCF) to monitor the protection of forests and wildlife, collection of intelligence and wildlife crime records.

As discussed elsewhere, WPA provides officers from the forest as well as police departments the power to enforce wildlife protection. There are two agencies involved in the enforcement of WPA with two different databases — one from NCRB (data available in the public domain), another from the protection, vigilance & wildlife crime bureau (data not available in the public domain).

Directorate of Revenue Intelligence (DRI), Central Board of Indirect Taxes & Customs (CBIC) and Wildlife Crime Data

DRI is under the Ministry of Finance, Government of India, vested with powers to collect intelligence about the smuggling of contraband including wildlife articles, keeping watch over critical seizures and investigation of cases and also to keep liaison with the Central Bureau of Investigation (CBI) and the International Criminal Police Organisation (INTERPOL) for coordination. Apart from the above mandates, DRI is responsible for keeping statistics of seizures and watching trends of smuggling and supply. Specific to seizures, month-wise seizure reports are available on the DRI website with a limitation. Seizure reports only contain limited information on what is seized, the quantum of seizure, the value of seizure, and where it was seized. With this data, it is not possible to draw inferences on the extent of illegal wildlife trade (Directorate of Revenue Intelligence, n.d.; *Express News Service, 2018*). Apart from DRI, CBIC has Air Intelligence Unit (AIU) and Seaport Intelligence Unit

(SIU). AIU and SIU are mandated to collect intelligence, identify the suspected passengers from Advanced Passenger Information System (APIS) and interrogate the suspected passengers to prohibit the smuggling of contrabands, including wildlife articles (*Ahuja, 2017; Express News Service, 2019*). During the exercise of writing this article, the researcher could not locate any data on wildlife article seizures from either AIU or SIU.

Wildlife Crime Control Bureau (WCCB) and Wildlife Crime Data

In 1994, the erstwhile Ministry of Environment and Forests (MoEF), Government of India, constituted a committee for the prevention of illegal trade in wildlife and wildlife products headed by Dr. S. Subramaniam to make recommendations. One of the recommendations of this committee was to establish a central task force designated as the Directorate of Prevention of Crime against Wildlife, as illegal trade in wildlife emerged as organised crime. The initial proposal to house the Directorate under the Ministry of Home Affairs (MHA) was not accepted. However, later the MHA agreed to the creation of a wildlife trade prevention bureau under the MoEF. In 2000, India promised at the 11th Conference of Parties (COP) of Convention on International Trade in Endangered Species (CITES) to establish a wildlife crime cell to tackle the growing menace of wildlife crimes. The name Wildlife Crime Control Bureau (WCCB) came in to existence in the year 2007, and it is now in operation from the year 2008.

WCCB has various missions like gathering intelligence related to wildlife crime, co-ordinate efforts and action between stakeholders, capacity building of enforcement officials, and so on. Among the above-said missions, the vital mission is to develop a Wildlife Crime Database Management System (WCDBMS) for better analysis of wildlife crime (WCCB, n.d.). In order to obtain wildlife crime data from all the States/UTs, WCCB through an advisory addressed to all the Principal Chief Conservators of Forests (PCCF) and Director Generals of Police (DGPs) to provide wildlife crime data reported if any within 48 hours to WCCB. However, through advisories from WCCB sent to the PCCFs and DGPs, it is known that information from these departments are not reaching the WCDBMS in time to initiate multi-agency efforts to counter wildlife crime (WCCB, 2015).

Against this background, the researcher completed an internship programme with the Southern Regional Office of WCCB in Chennai during the month of May and June 2019. The Regional Deputy Director and Wildlife Inspector has given an assignment to the researcher to submit a report on already existing WCDBMS. The researcher has conducted extensive work for two months on WCDBMS and submitted the report to WCCB. As an intern, the researcher learned that WCCB had created an online WCDBMS to get real-time wildlife crime data from the police as well as forest officials. In this regard, a username and password were shared with the police/forest department for timely reportage of wildlife crime from all over India. The Police/forest department has to provide

details like date and time of the offence, nature of the offence, place of seizure/ arrest made, details of wildlife articles seized including its common name and scientific name along with the personal details of the accused, etc.

Wildlife Crime Database Management System

An essential prerequisite of any law enforcement agency is the ability to share information and intelligence quickly and securely among stakeholders. With the advent of information and communication technology, data has become fundamental for every law enforcement agency. Information and intelligence have been collected in the form of data and stored in the crime databases. Around the world, police, and intelligence agencies have been developing a robust crime database in order to anticipate, prevent, and monitor criminal activity. These databases have both covert and overt intelligence. Though crime databases are a vital tool for law enforcement, due to poor design, they seem to be imperfect. Fundamental errors in data entry or information categorisation will cause difficulties in locating vital information in the database when needed. However, with proper and systematic planning, a useful database can be designed that will discriminate between relevant and irrelevant information. In light of the above, wildlife crime databases are vital information systems that help enforcement officers to detect, prevent wildlife crimes, and pursue criminals (The World Bank, 2018). Building a robust crime database for conventional crimes is complicated as it has various crime heads like homicide, rape, sexual harassment, cheating, forgery, abduction, robbery, assault, burglary, etc. However, for wildlife crime, designing a crime database is not difficult as its nature and scope are very narrow.

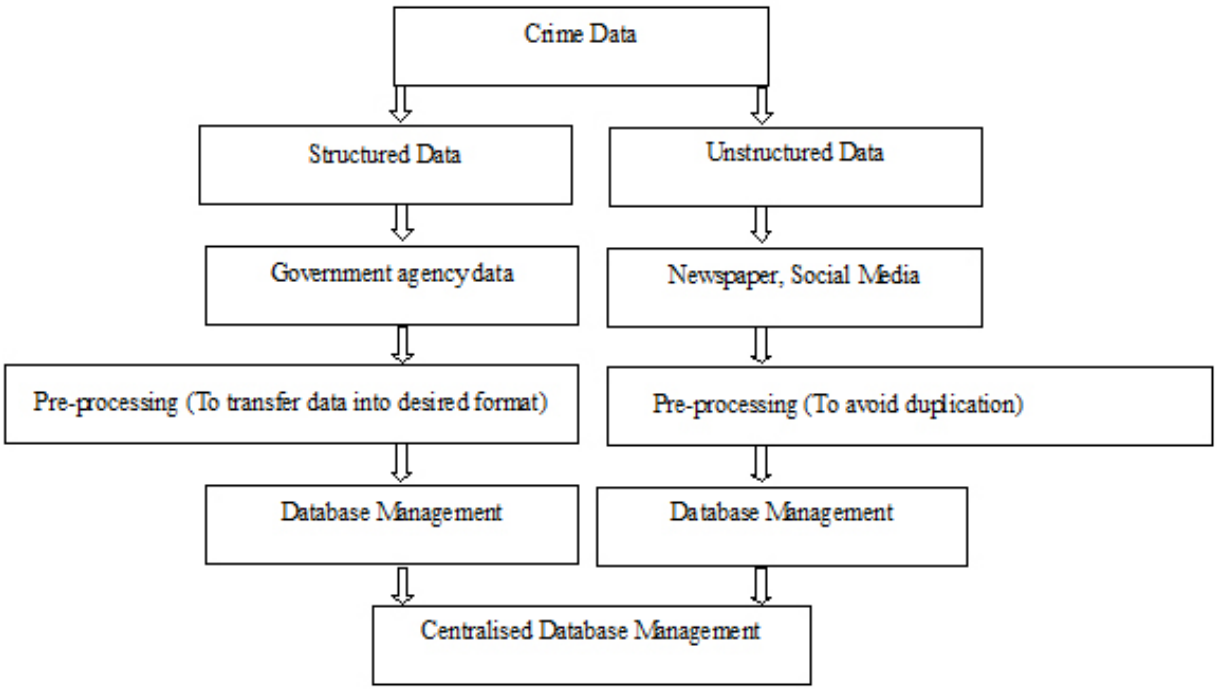
Since conventional/traditional crime prevention mechanisms followed by government agencies were not sufficient for long-term implications, it necessitates the emergence of crime data analytics. With the advanced technologies that continuously generate and exchange data, data analytics could be employed to predict crimes. Crime analytic scientists distinguish data into two types — structured data and unstructured data (*Tao et al., 2018*). The following framework gives the overall picture of crime data analytics.WCCB has developed an online WCDBMS to get real-time data in order to analyse trends in crime and develop effective measures to prevent and detect wildlife crime across India (*Press Information Bureau, 2018*). From the above framework, it is understood that WCDBMS is a Government agency data that is not pre-processed. Hence, the data in the WCDBMS has not undergone the process — cleaning, integration, transformation, and reduction. The existing WCDBMS needs a complete revamp in order to attain its full potential to combat wildlife crime in India.

Further upgradation to the WCDBMS

There has been a strong push for evidence-based policing around the world in recent years from researchers,

practitioners, and policymakers. Although there is no single definition of the concept, evidence-based policing generally refers to police strategies and tactics being guided by scientific evidence of effectiveness. This evidence can take many forms, although the evidence-based movement frequently turns to results from methodologically rigorous work and in particular randomised experiments and quasi-experiments that can provide the most believable answer to questions of whether a strategy or tactic works (*Telep, 2018*). Evidence-based policing is majorly dependent upon closed intelligence and open intelligence. As mentioned in Figure 1, through WCDBMS, we are collecting structured data (closed intelligence) and unstructured data (open intelligence). The combination of structured and unstructured data will give effective results while doing analysis. So, in order to capture unstructured data, a parallel database management system could be established in order to have open intelligence. In this era of technological advancements, collecting and collating open intelligence becomes doable with the help of online media (news and investigative journalism websites and others), and social media networks (Twitter, Facebook, ect.), e-commerce websites (Flipkart, Amazon, etc.). Hence, it is suggested that WCCB could also establish an open intelligence database system in order to combat new forms of wildlife crimes in India.

Figure 1

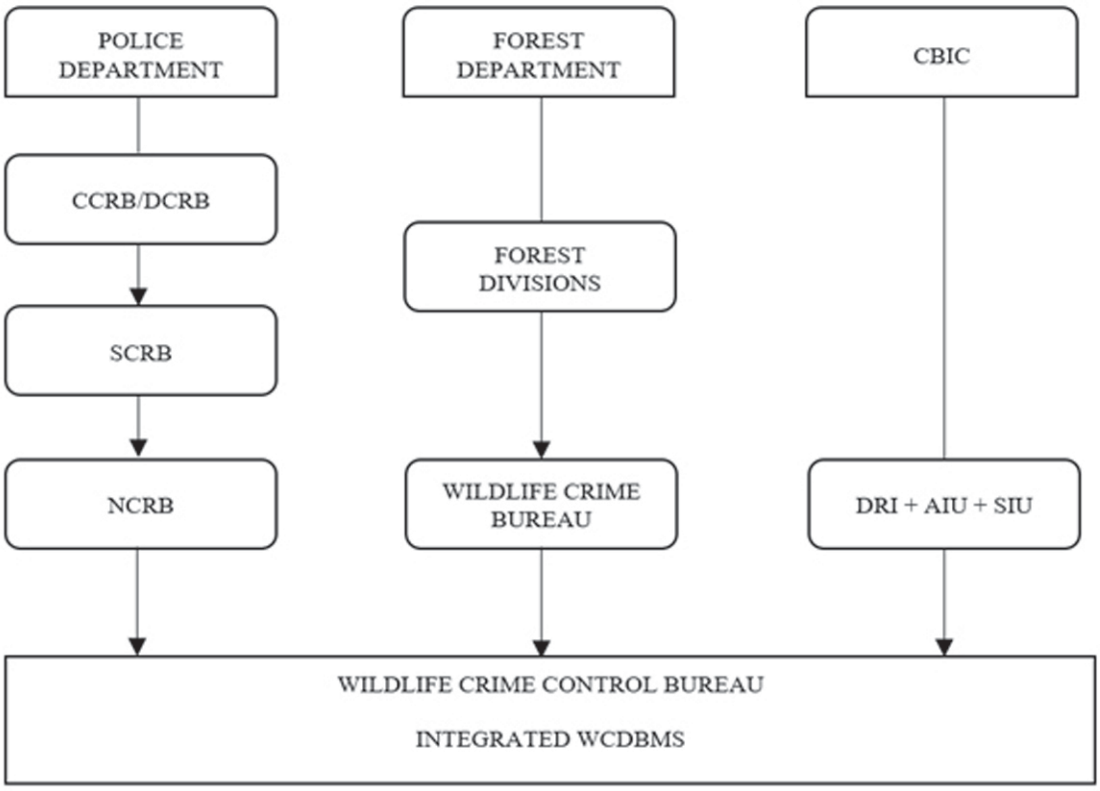


Need for Wildlife Crime Data Integration

In light of the above observations, it is understood that we already have a database on wildlife crime by the police and forest departments of respective states. Moreover, with the effort taken by WCCB, there is a system in place to collate wildlife crime data from both police and forest departments, respectively. Wildlife seizure data from CBIC has to be shared with WCCB in order to make it visible in WCDBMS. All required now is to integrate the available data sources into a single database (*Refer Figure 2*). Further, make it available in a public domain in order to ensure public access to information aslike NCRB publishes *"Crime in India"*. The following figure illustrates the proposed wildlife data integration model.

In this background, WCCB may be designated as a nodal agency to integrate wildlife crime data from all the above-said sources. As WCCB already has WCDBMS, immediate attention should be on improving the mechanisms to ensure real-time reportage of wildlife crimes from the police as well as the forest department. Furthermore, it is pertinent to bring in the old wildlife crime data from all the relevant stakeholders to WCDBMS. The significant step WCCB has to undertake is to make those wildlife

Figure 2



crime data available for public information. Any information that would lead to locating any accused should not be made available in the public domain in order to ensure the privacy of the accused. Table 2 gives an overview of existing wildlife crime heads as in *Crime in India* statistics. Table 3 suggests that some new heads be added to existing wildlife crime data.

Need for a Crime Analyst for WCCB and TNFD

The International Association of Crime Analysts (2014) defines crime analysis as a profession and process in which a set of quantitative and qualitative techniques are used to analyse data valuable to police agencies and their communities. It includes the

Table 2

Data heads available in existing wildlife crime data

S.No.	Existing data heads	Source of data
1.	State/UT wise incidence reported	Crime in India, NCRB
2.	State/UT wise number of persons arrested	Crime in India, NCRB
3.	Disposal of wildlife crime by police	Crime in India, NCRB
4.	Disposal of wildlife crime by courts	Crime in India, NCRB

Table 3

Suggested heads to be incorporated to the wildlife crime data

S.No.	Suggested data heads	Explanation
1.	Date of case registration	Date on which the wildlife crime case is registered
2.	Name of the State/UT	List of States and Union Territories
3.	Name of the District	List of Districts within the selected State/UT
4.	Name of the forest division/ police station	List of the forest division/police station within district selected
5.	Crime No.	If Forest Dept./WCCB (e.g. WLOR No.___/2020) If police FIR No._____/2020
6.	Category of wildlife offence(s) under Wild Life (Protection) Act, 1972	• Hunting • Picking, uprooting, etc. of specified plants • Unauthorised possession, transport and trade • Protected areas/habitat destruction
7.	Species name	List of the common names (with scientific name in bracket) of the species under schedule I, II, III and IV of WPA. E.g. Spotted deer (Axis axis) Sch. III

8.	Current status of the case	• Under investigation • Under trial
9.	Disposal status of the case	• Acquitted • Compounded • Convicted • Discharged

analysis of crime and criminals, crime victims, disorder, quality of life issues, traffic issues, and internal police operations, and its results support criminal investigation and prosecution, patrol activities, crime prevention and reduction strategies, problem-solving, and the evaluation of police efforts. Crime analysts are the problem solvers within law enforcement agencies utilising analytical methods and theoretical knowledge to assist their functions*(Drawve et al., 2018)*. Since the researcher is interviewing Tamil Nadu Forest Department officials for his Ph.D. research on wildlife crime prevention, they informed that they are already occupied with various responsibilities. Hence, they could not even enter the data to the WCDBMS on time. So, there is a need for full-time crime analysts to take care of the WCDBMS. A crime analyst could analyse wildlife crime and use wildlife crimes data to forecast when and where criminals are likely to strike. Based on the data, it is possible to detect and understand distinctions among wildlife crime patterns. With the use of crime and intelligence data, a crime analyst can design a directed patrol or tactical action plan that would result in an effective response. The crime analyst will collect data, subject it to statistical tests, develop and test hypotheses, and write conclusions that adhere to commonly accepted criminal justice research standards. A person from the academic discipline of Criminology would fulfil the responsibility of a crime analyst. The skill for crime analysis will not be acquired by completing a post-graduate degree in Criminology; it is solely acquired by practice and experience. Hence, it is suggested that a person with a post-graduate degree in Criminology and its allied subjects like Criminal Justice Administration, Police Administration with at least two years of research experience/data analytic skills with proficiency in using Statistical Package for the Social Sciences (SPSS) and R programming/ Python language and geographic information system application (for example QGIS) could be a prerequisite qualification for the post of crime analyst with the WCCB and PV&WCB. As mentioned in Figure 1, a full-time crime analyst could do the pre-processing of the data entered in the WCDBMS by various officials from all over India and clean the data to remove any errors or gaps. Thus, only quality data alone will be available in the WCDBMS; this will allow drawing various inferences in order to use the data better for the functioning of WCCB and state forest departments.

Conclusion

Wellness of forests are dependent on the protection of wildlife. By ensuring the protection of wildlife, it is very much possible to protect forests. One step towards ensuring wildlife protection is the enforcement of WPA to a larger extent. In order to measure the extent of enforcement of WPA, wildlife crime data becomes a crucial indicator. As discussed elsewhere, wildlife crime databases are a vital information system that helps enforcement officers to detect, prevent, and pursue criminals. Hence, a centralised, integrated wildlife crime database becomes the need of the hour. The responsibility of the government does not end there on the creation of an integrated wildlife crime database unless the data is accessible to the public. Also, to bring most out of the integrated wildlife crime data, the role of a crime analyst becomes essential to draw actionable inferences from the available data. India should march towards data-driven enforcement to protect its wildlife.

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CARBON SEQUESTRATION

Arumugam Abirami*

Abstract

Carbon sequestration is a long-term process of storing carbon in geological formations, soils, oceans and most importantly in plants. Apart from natural decomposition of plants and animals, carbon dioxide is released into the atmosphere through anthropogenic activities. Carbon dioxide absorbs infrared radiation. As carbon dioxide concentration increases, the average temperature of the earth's atmosphere rises, leading to global warming. According to Inter-governmental Panel on climate change, improved crop and grazing land management, use of organic fertilizers, tillage practices, restoration of organic soils and restoration of degraded lands can help in removal of carbon dioxide at a low cost. Carbon capture and storage is a process, where the carbon dioxide gas is separated, compressed, transported and stored at certain geological formations. Air pollution control, ocean fertilization, re-forestation, afforestation are some of the methods for carbon sequestration.

Keywords: Carbon sequestration, afforestation, Agroforestry, soil fertility, agricultural practices enhancement.

Introduction

It is the process of capturing and storing atmospheric carbon dioxide; also a method of reducing the amount of carbon dioxide in the atmosphere. Carbon is added to soils through the death and deposition of biomass of higher plants, which assimilate CO_2 from the atmosphere. Organic compounds of the plant tissues are the food materials for microorganisms in the soil. The metabolic activities of microorganisms and other macro organisms such as earthworms release CO_2 into the atmosphere in the process of respiration (Paustian, 2005). Carbon input or output is determined by certain environmental factors: vegetation types, soil fertility, activity of decomposer organisms, tillage practices, land use change etc. Another process called biosequestration is through biological process. This usually

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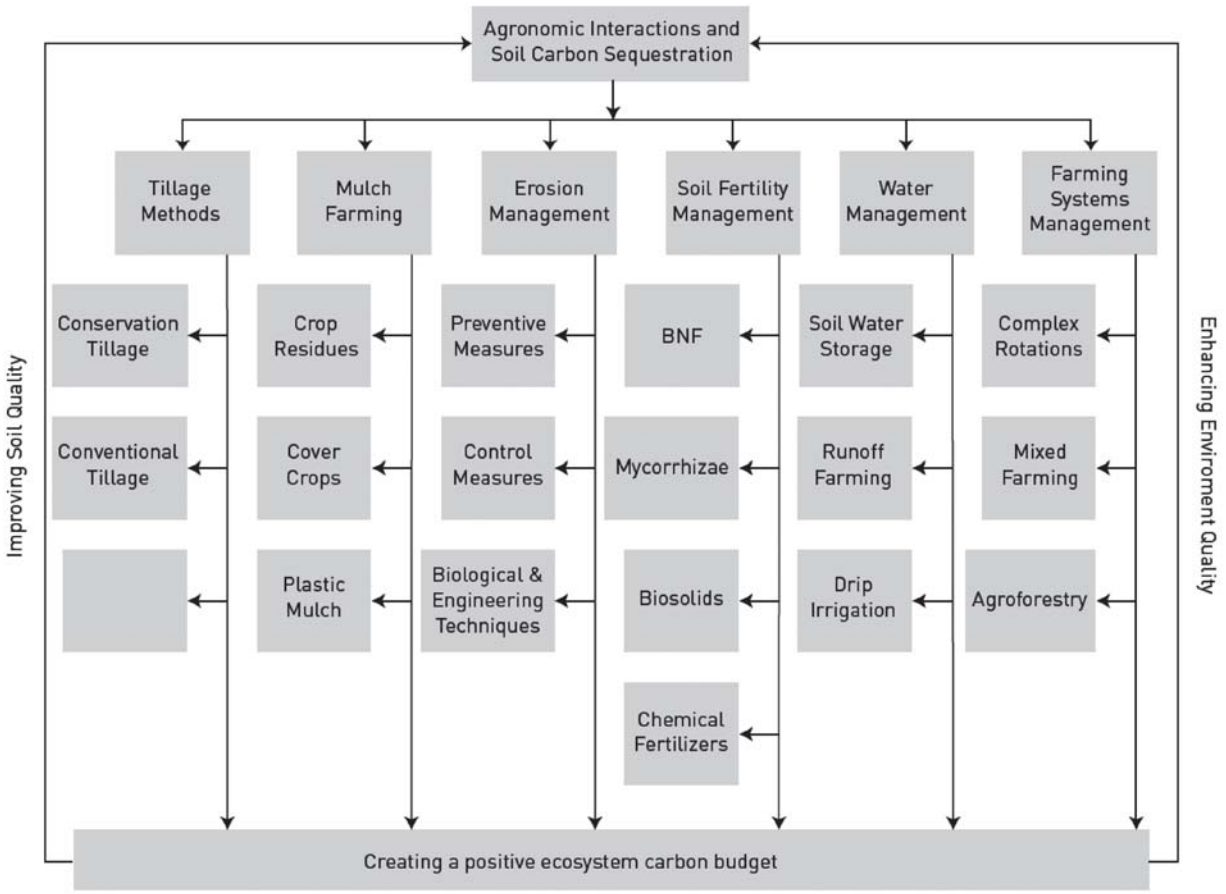
takes place in peat lands, afforestation, reforestation, urban forestry, wetland restoration and agriculture.

Carbon sequestration in soil

Organic matter found in the soil includes all its organic components, especially undecomposed plant and animal tissues, as well as products of their partial decomposition. It follows that the vegetation located on the soil surface has a huge impact on the composition of its organic matter. It is made of high molecular weight organic substances such as polysaccharides and proteins as well as low molecular weight and uncomplicated structure like sugars and amino acids (Quideau *et al.,* 2001). In general, all compounds found in the soil that have organic carbon in their structure will belong to soil organic matter. Living organisms are usually not classified as organic soil substances (Di Lonardo *et al.,* 2017). The process of Carbon sequestration in soil is usually carried out by plants through photosynthesis, with carbon stored in the form of organic carbon. In arid and semi-arid climates, soil carbon sequestration occur in the conversion of CO_2 from air found in soil into inorganic forms such as secondary carbonates (Lal, 2004). There is no single strategy for soil carbon sequestration potential. A combination of passive and active management techniques is the most effective process for maximizing the SC potential; also other strategies can be used for low-carbon land use and a substitute for fossil fuel (Bell *et al.,* 2020). Soil organic carbon plays an important role in maintenance of soil fertility. Forest lands determine the carbon cycle and any disturbances to it results in climate change. Conservation tillage, cover cropping, organic crop production and crop rotation can increase soil organic carbon (Hammad *et al.,* 2020). Any Change in soil texture and structure is based on soil organic matter. It can also lead to increase in drought resistance crops and higher yield. In the above ground of terrestrial ecosystems, Carbon sequestration depends almost exclusively on plants, which are also the main sources of organic matter stored in living organisms and dead matter deposited in the soil. Most of the organic carbon accumulated in the soil in the form of humic substances also derives from remnants of plant constituents and tissues. Soil stores much more carbon than the above ground environment, but levels vary greatly with environmental conditions (Lorenz *et al.,* 2009 and Carrenho and de Cesaro Krzyzanski, 2020).

Decomposition of plant residues and other organic materials in the soil is a source of Carbon and nutrients for new growth of microbial communities and plants. Much of this Carbon is released back into the atmosphere as CO_2 during respiration, or is incorporated into living biomass. However, about one-third of SOM breaks down much more slowly and could still be present in the soil after 1 year (Angers and Chenu, 1997). This suspended organic matter represents a significant carbon store and can remain in the soil for extended periods as a part of soil aggregates. The fraction of soil organic matter that is so ''protected'' from further rapid decomposition is very important from the point of view of Soil Carbon Sequestration (Nair *et al.,* 2010).



Source: Lal, FAO Report

Carbon Sequestration in Agroforestry

Agroforestry is a practice of introducing trees in farming and it has a significant role in enhancing land productivity and improving livelihoods of farming communities across the world. Carbon sequestration through afforestation and reforestation of degraded natural forests is being useful in climate change mitigation and reduction of per capita carbon footprint. The planting of trees along with crops improves soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of streams and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock. It also has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change (Makundi and Sathaye, 2004, Murthy *et al.,* 2013).

Social forestry and Agroforestry

Social Forestry is defined as 'Forestry outside the conventional forests which primarily aim at providing continuous flow of goods and services for the benefit of people. This definition implies that

the production of forest goods for the needs of the local people is social forestry. Thus, social forestry aims at growing forests of the choice of the local population. Agroforestry is any sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and eco-logical conditions of the area.

National Agroforestry Policy, 2014

The National Agroforestry Policy deals with the practice of integrating trees, crops and livestock on the same plot of land. It has the potential to achieve sustainability in agriculture while optimizing its productivity and mitigating climate change impact. The policy talks of coordination, convergence and synergy between various elements of agroforestry, scattered across various existing missions, programmes and schemes under different ministries—agriculture, rural development and environment. The policy would be implemented through an integrated agroforestry mission or board. Over 80 per cent of the farmers in India are small land-holders, owning less than two hectares and 60 per cent of the cultivated area; they rely on rains for irrigation. These rain-fed farms are under stress because of absence of assured irrigation and low biodiversity. Agroforestry can also help in reducing unemployment. At present, over one billion hectares of agricultural land, almost half of the world's farmland, have more than 10 percent of their area covered by trees. Out of it, 160 million hectares have more than 50 per cent tree cover. As the amount of global forest shrinks, growing trees on farms for all kinds of purposes become more important (Jitendra, 2015). It aims in encouraging and expanding tree plantation in an integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households; protection and stabilization of ecosystems and promoting resilient cropping and farming practices; self-reliance of raw materials to save foreign exchanges; supplementing the availability of agroforestry products; developing capacity and strengthen research in agroforestry to minimize pressure on existing forestlands.

Dhyani *et al.,* (2016) studied the potential of agroforestry systems in carbon sequestration in India and reported that agroforestry systems in addition to accumulate and sequester carbon, provide an excellent opportunity to increase the tree cover to a significant level of the total geographic area of the country. The following table gives the Carbon Sequestration Potential (CSP) of trees in India.

Region	Agroforestry system	Tree species	No. of trees / hectare	Age of the trees (year)	CSP (mg C/ha/ year)
Himalaya	Block plantation	*Eucalyptus* sp.	2500 – 2800	3.5	5.90
		Tectona grandis	570	10	3.74
		Cedrus deodara	100	19	2.47
	Agrihortipasture	*Malus domestica*	1000	7	15.91
	Grove silvipasture	*Bambusa spp.*	11033	4	19.14
	Farm forestry	*Acacia catechu, Pinus spp.*	-	30	1.5
Indo Gangetic	Agrisilviculture	*Leucaena* sp	10666	6	10.48
		Populus deltoids	400	7	1.98
	Block plantation	*Acacia nilotica*	1250	7	2.81
		Dalbergia sissoo	1250	7	5.37
		Prosopsis juliflora	1250	7	6.50
Humid and sub-humid	Agrisilviculture	*Gmelina arborea*	592	5	3.23
	Forest plantation	*Eucalyptus spp*		6	2.18
	Block plantation	*Gmelina arborea*	452	20	3.95
	Silviculture	*Tectona grandis*	444	20	3.32
Arid and semi arid	Block plantation	*Albizia procera*	312	10	1.79
		Albizia amara	312	10	1.00
		Leucaena sp.	2500	9	10.32
		Eucalyptus sp.	2500	9	8.01
		Albizia lebbeck	625	9	0.62
		Acacia albida	1111	9	0.82
		Acacia farnesiana	170	2	2.42
	Agrisilviculture	*Albizia procera*	312	7	3.70
		Acacia pendula	1666	5.3	0.43
		Leucaena sp	11111	4	2.77
		Casuarina	833	4	1.57
	Silvipasture	*Acacia nilotica* + Natural pasture	312	5	1.9 – 5.4
		Dalbergia sissoo + Natural Pasture	312	5	2.5
Tropical	Home garden	Mixed tree species	667	71	1.60
	Block plantation	*Eucalyptus spp., Acacia mangium*	5000	6.5	12.59

Source: Newaj *et al.,* (2014), Dhyani *et al.,*(2016)

Carbon Sequestration in Ocean

Oceans are one of the most promising places to sequester carbon. It covers approximately 70 % of the earth's surface, its average depth is about 3800 metres, and the deeper layers of the ocean are greatly unsaturated with regard to CO_2 and its dissolved forms, carbonic and bicarbonic acid, and their salts. A cubic km of deep ocean water contains about $3x10^{10}$ g carbon (Wilson, 1992). Thus, the total carbon content of the deep ocean (> 500 m) is approximately $5.1x10^{22}$ g. At present, anthropogenic emissions of carbon equal about $6.8x10^{15}$ g y^{-1}. If all the emissions were injected into the deep ocean, they would scarcely make a dent in the deep ocean's carbon content (Golomb and Pennell, 2010).

At the same time, the ocean pH in the deep ocean has shown a decreasing trend when compared with the surface ocean. Rising concentrations of greenhouse gases in the atmosphere are implicated in climate changes and a significant percentage is attributed to CO_2. There are two major methods of ocean carbon sequestration – direct injection and ocean fertilization (photosynthetic fixation of CO_2 by ocean organisms). From the ocean surface to depths of about 500 metres CO_2 would exist as a gas and would tend to rise in the water column, since it is less dense than seawater. Between 500 metres and 2,700 metres CO_2 would exist as a liquid, but one that is still lighter than seawater and would thus also rise in the water column. At depths up to 2,700 meters CO_2 will create a rising plume and dissolve into the surrounding seawater relatively quickly. At depths deeper than 3,000 metres the weight of the water column compresses the liquid CO_2 and it becomes denser than seawater and sinks slowly to the seafloor. As a solid (or as a hydrate at depths below 400 metres) it will also sink, but will dissolve as it descends in the water column. Once the carbon dioxide sinks to the seafloor it forms an underwater pool at the bottom of the ocean, trapped in place by its own density (Hume, 2018).

Benefits

- Storage of CO_2 in the ocean accelerates this natural storage process. It transports CO_2 from the atmosphere to the deep ocean, where it will eventually wind-up, and do less harm.

- The effectiveness of ocean storage of CO_2 depends on how long the stored CO_2 remains isolated from the atmosphere. Ocean currents carry surface waters to the deep and vice versa. This mixing effect is more pronounced near the surface and generally decreases with depth. For seawater in the deep reaches, it can take between 300 to 1,000 years for seawater to go through a complete turnover. If our goal is to keep stored CO_2 separated from the atmosphere as long as possible, then deeper is better. According to models, if the storage site is below 3,000 metres the fraction of CO_2 that might reach the atmosphere is expected to be 20 percent over 200 years.

- Once an oil well is emptied it might be repurposed as an underground

CO_2 storage reservoir, but this depends on the geology. According to the International Energy Agency's Greenhouse Gas R&D Programme, the world's hydrocarbon reservoirs have a combined storage capacity of roughly 800 gigatons of CO_2 ($GtCO_2$). To put this number in perspective, the world's annual CO_2 emissions are currently around 36 $GtCO_2$. In other words, terrestrial storage could handle about 22 years' worth of emissions at our current levels.

- Climate change experts often refer to what is called our "carbon budget." This is the amount of carbon that we can emit into the atmosphere without causing a two-degree celsius temperature change. It's perhaps one of the most important metrics to monitor since it will impact life on earth for at least the next century.

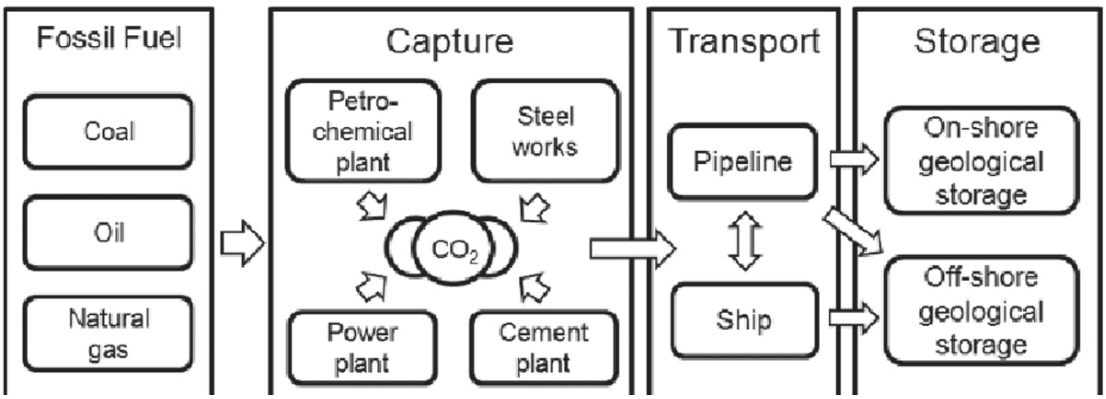
CO_2 sequestration first involves capture from their sources, of which one major type is of the coal-fired power plant. The CO_2 emissions are relatively pure from coal-fired power plants and could be isolated and injected into the ocean. A typical 500 MW power plant produces about 130 kg/s of CO_2. After CO_2 capture, the CO_2 would be transported to the ocean via a pipe or ship to the ocean for direct injection. Technologies for CO_2 direct injection include: Liquid CO_2 droplets, CO_2 laden seawater, Solid CO_2 (dry ice) and CO_2 lake formation. At acute levels CO_2 has a narcotic effect on animals and causes respiratory distress and death. Non-lethal effects have also been observed due to hypercapnia (elevated CO_2 exposure). The primary effect of acidified seawater exposure by organisms is acidosis, the decrease of pH in body fluids. Intracellular and extracellular processes have been shown to be disrupted when seawater pH drops to a range of about 6.0 – 7.8. Many marine animals counter acidosis by increasing bicarbonate ion production (e.g. in the gills) (Chow, 2014).

Valorization of carbon dioxide

Apart from carbon capture and storage, CO_2 can be managed by reusing it in other ways instead of emitting it to the atmosphere. It can be used for the production of raw materials (methane, light olefin), synthesis of advanced materials, production of fuels (methanol, biodiesel) and as a solvent (supercritical extraction). The dry reforming is a reaction through which the carbon dioxide reacts with a methane stream to produce the syngas, a mixture of carbon monoxide and hydrogen. CO_2 can be generated from the combustion of coal or biomass. The CO_2 based methanation interest is increasing mainly in countries with large coal resources, such as U.S., China and India. The synthetic methane produced can be distributed in natural gas pipeline and can feed the natural gas internal combustion engine for the automotive sector or can be used in boilers for domestic heating. Carbon dioxide can be fed to greenhouses for microalgae cultivation photosynthetic processes. Such microalgae are cultivated in open ponds or photo-bio-reactors where carbon dioxide can be bubbled from the down, thus increasing the photosynthetic efficiencies and the biomass productivity in comparison with other cultivated biomass. The Supercritical Fluid Extraction (SFE)

process is a preindustrial technology, already applied in some high added value productions. Among the supercritical fluids that can be applied, carbon dioxide is the most interesting for the low cost, the high availability and the low critical temperature (31°C at 73 bar). Many applications of the CO_2-SFE have been realized in the food processing units (de Falco, 2013).

- Conservation of water in the root zone to increase green water component by reducing losses through runoff, evaporation and increasing the efficiency through drip irrigation / fertigation techniques.
- Improvement of grazing systems that enhance the diet of livestock.
- Better use of complex farming systems including mixed crop-livestock and agroforestry techniques that efficiently use resources and enhance biodiversity (Lal, FAO report).



Source: Gim *et al.,* (2013)

Recommended Management practices

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ORNAMENTAL GARDENING AND PARKS IN CHENNAI – A REVIEW

P. Sudhakar*

Abstract

Ornamental gardening is an aesthetic blend of art, nature and science. Gardens have existed throughout the world in most ancient civilisations. Rapid growth of public gardens with plant collections from several parts of the world began in the 17th century. Scientific gardens were established with a number of introduced species of economic and aesthetic importance, as well as native species of conservation importance. These botanical gardens were centres of germplasm collection, nature education and economic activity. British gardens spread the passion for horticulture and were resources for seeds and other planting materials for the public. Parks as primary recreation spaces were established in the urban landscapes which become places for solitude and contemplation, festivities, social gatherings, study, leisure, painting, poetry, music and everyday activities. In this trend of urbanisation, parks being the green spaces and lungs of the cities are the need of the hour. Green space is one component of biodiversity management and the most obvious.

Keywords : Garden, Parks, green space, green cover, conservation

Introduction

Ornamental gardening is an aesthetic blend of art, nature and science. Gardens formed an important feature of landscapes in all ancient human civilisations. All religious mythologies depict gardens as important places for major events in history. The Bible mentions Garden of Eden created by God for Adam and Eve. Ramayana talks about Ashokavana, a place where Sita was imprisoned. Sabha Parva of Mahabaratha describes the layout of gardens, parks and artificial lakes in the city of Indraprastha (Prakash, 2001).

The terms garden and park are often used interchangeably. The meaning of garden according to Oxford dictionary is 'piece of ground for growing flowers, fruits or vegetables and as a place of recreation.' Similarly it also refers a park as 'large public garden in a town for recreation.' (Pearsal, 2011). These terms are also used for a variety of meanings.

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According to the Chennai Corporation, whenever the Open Space Reserve (OSR) lands are handed over to the corporation they are converted into parks. (*www.chennaicorporation.gov.in*).

History of Gardening

The earliest physical evidence for ornamental landscape comes from Egyptian tomb paintings about 3500 years ago (Turner, 2005). Gardens have existed throughout the world in most ancient civilisations.

Persian Gardens

Gardens of Persia were well known for their engineering marvels and novel designs (Khonsari *et al.* 1998). Hanging gardens of Babylon (present day Iraq) which is one of the seven wonders of ancient history was a landmark in the history of gardening. Persian gardens were designed with an underground aquaducts called 'qanats' that helped to create lush gardens in a dry region (Newton, 1979).

Gardens of Europe

Ornamental gardens became immensely popular in Europe right from the medieval period. Italy was known for its renaissance gardens of the late 15th and 16th centuries (Attlee, 2006). Each country in Europe such as Britain, Portugal, Greece, France, and Spain has developed unique designs of gardening (Turner, 2005). From the 17th century onwards Europe witnessed rapid growth of public gardens which harboured plant collections from several parts of the world. These botanical gardens have also become centres of germplasm collection, nature education and economic activity (Huxley, 1992).

Gardens of Asia

There is a lot of literature available on gardens of China, India and Japan. Chinese gardens were initially developed as medicinal gardens and expanded later with a larger scope (Chen and Gang, 2011). These gardens have also become places for solitude and contemplation, festivities, social gatherings, study, leisure, romance, painting, poetry, music and everyday activities (Smith, 2009). Bamboo, pine, lotus, chrysanthemum, banana and sweet olives were among the plants cultivated in Chinese gardens.

Japanese gardens were developed based on the designs of Chinese gardens to some extent. In Japanese gardens the trees were sheared into mountain shapes. The technique of Bonsai was introduced by the Japanese. Stone elements formed an integral part of Japanese landscape. Water source in Japanese gardens is found to appear as part of natural surroundings. Japanese gardens have also been adapted to Western settings from the 19th century (Miller, 2005).

India was a forerunner in having well planned urban landscapes dating back to 3000 BC (Thapar, 1966, 2010). Features of natural landscapes were incorporated in royal gardens and urban public parks of ancient India (Sinha & Sinha 2001). Systematic establishment of parks and avenues

was done during the rule of King Ashoka. Ashoka meticulously planned both location and components of the parks which included a water pool, arbour, creepers and shaded pavements (Prabhakar, 1993). There are numerous references in the Sanskrit literature on the early gardens of India which talk about different types of gardens such as *pramadodyan*, *udyan*, *vrikshavatika* and *nandanavana* (Prakash, 2001).

Mughals in India established a unique garden style. They reflected the Quranic sense of paradise (Wescoat, 1986). Mughal gardens are of three types: tomb gardens, pleasure gardens and courtyard gardens (Prabhakar, 1993). These gardens were also a symbol of power and wealth of the empire.

The British colonial period earmarked another milestone in the history of gardens in India. It is during the British period that the distinction between parks and gardens was well established. Scientific gardens were established with a number of introduced species of economic and aesthetic importance as well as native species of conservation importance, whereas, parks as primary recreation spaces were established in the urban landscapes (Khanna, 2008). Spacious lawns became a major focal feature of British gardens (Roberts, 1998). British gardens spread the passion for horticulture and were resources for seeds and other planting material for the public. The major Botanic gardens established by them include Acharya Jagadish Chandra Bose Indian Botanic Garden, Kolkota, Lal Bagh, Bengaluru, Sims Park, Coonoor and Botanical Garden, Ooty (Khanna, 2008).

Post-Independent Urban Spaces and Parks in India

According to the United Nations sources India will have over 241 million workforce of people between 2010 to 2030. The changes that are taking place in ecology, economy and society are due to the result of rapid urbanization in India (Defries and Pandey, 2010).

Industrial revolutions in the 1970s followed by globalisation in the 1990s have expanded urbanization in India. The rate of urbanization is much faster in the last decade when compared to early periods (Rahman, 2007). The increase in urban landscape especially of the cities is quite expensive. Several capitals of Indian states have increased their urban scale by leaps and bounds. The percentage of expansion of Delhi for example is 2264% which has encroached neighbourhood states of Haryana, Rajasthan, Uttarakhand and Uttar Pradesh. Similarly Mumbai and Chennai have grown by 727% and 675% respectively (Table – 1).

Though the cities have expanded by large proportions, the quality of the city environment has improved little. One of the major indicators of the environmental quality of an area is the green cover (EPI, 2010). The percentage of green cover in several cities of India is very meagre and has not increased proportionately (Chaudhry, Bagra, & Singh, 2009). Chandigarh has the highest percentage of green cover among the Indian cities followed by Delhi (Table – 1).

The major contributors of tree cover in cities are the parks. There is a direct

Table – 1. Growth of Urban Areas in Major Cities

S.No	Name of The City	Area before Expansion in KM^2	Area After Expansion in KM^2	% of Expansion
1	Delhi	1483	33,578 (NCT)	2264%
2	Mumbai	603*	4,355 (MMR)	727%
3	Chennai	176	1189(Greater Chennai)	675%
4	Kolkata	185	1851.43(KMDA)	642%
5	Hyderabad	172	650(GHMC)	377%
6	Bhubaneswar	135	419	310%
7	Bhopal	298	696	233%
8	Bengaluru	360	741 (BBNB)	206%
9	Ahmedabad	298	475	159%
10	Jaipur	168	200.4	119%

* Includes Mumbai Suburban

(Sources: www.mmrdamumbai.org. www.chennaicorporation.gov.in. wwwmcdonline.gov.in. .www.kmdaonline.gov.in http://bbmp.gov.in., www.ghmc.gov.in., www.bdabbsr.in., www.amcgujarat.com. http://jaipurjda.org., www.bhopalmunicipal.com.) Not helpful? You can block www.mmrdamumbai.org results when you're signed in to search.www.mmrdamumbai.org

Table - 1. Major Cities with percentage (%) of Green cover

S.No.	Name of the City	Percentage (%) of Green Cover
1	Chandigarh	46.0
2	Delhi	21.1
3	Hyderabad	8.61
4	Chennai City	6.8
5	Bengaluru	6.46
6	Mumbai City	1.91

(Source: ISFR -2019; https://indianexpress.com/article/cities/chandigarh/green-cover-of-chandigarh, https://thesoftcopy.in/2018/11/23/bangalores-green-cover)

proportion between the number of parks and percentage of green cover, though the green cover is also based on the trees and reserves outside the parks. Parks are the much needed green space and function as lungs of cities (Table – 2).

History of Chennai

Chennai city formerly known as Madras is the capital city of Tamil Nadu lying between 12^0 9' and 13^0 9' of the northern latitude and 80^0 12' and 80^0 19' of the eastern longitude. The city is

Table - 2 Number of Parks in Some Cities

S.No.	Name of the City	No. of Parks
1.	Delhi	18,000
2.	Chandigarh	1807
4.	Bengaluru	1115
3.	Hyderabad	709
5.	Mumbai	282
6.	Chennai	525
7.	Ahmedabad	202
8.	Bhubaneswar	32

(Source: www.egovamc.com www.chennaicorporation.gov.in, http://bbmp.gov.in, http://mcchandigarh.gov.in, www.ghmc.gov.in, www.mmrdamumbai.org. wwwmcdonline.gov.in. www.bdabbsr.in.)

situated more or less on a flat plain. The average elevation is around 6.7 metres (District Profile, Govt. of Tamil Nadu) and its highest point is 60 m (Pulikesi *et al.* 2006).

The city receives rainfall from both the south-west and the north-east monsoons. The average annual rainfall is about 130 cms, the maximum rainfall being received during the north-east monsoon. The relative humidity is about 80-85% during the rainy months and 55-60% during summer. The maximum day temperature during December-January is about 28^{0}C and in summer (April – May) it is 38^0 – 44^{0}C. The soil in Chennai is of four types. They are red loamy, sandy, clayey and lateritic soils. The history of Chennai has been well documented by the city historian, S. Muthiah (1989, 1990, 1995, 2000, 2004,).

The Chennai city of today had its origins on a small strip of land leased from the Nayaks of the Vijayanagar Kingdom. It had been ruled, successively, by the Pallavas between the 6th century A.D. and the 9th century A.D., and by the Cholas from the 10th to the 14th century A.D. The Vijayanagar kings ruled this area from the 14th to the 16th century A.D. The Sultanate of the Deccan ruled Madras in the 16th century and the Mughals in the 17th century. Chennai city was founded on the Coromandel Coast in peninsular India in 1639 by Francis Day, a British man. The city experienced a strong European influence, mainly the English, and to a lesser extent, the French, Dutch, Portuguese and Danish from 1650 AD onwards (Raman and Prasad, 2010). It is the fourth largest and densely populated city in present day India with a total area of 178.20 sq. kms, and a population of over 7 million.

The Expansion of Chennai

The phase of urbanization of Chennai is remarkable among the cities of South India. The birth of Chennai was on 22nd August, 1639. This date is marked based on the official handover of the small strip of land by the local Nayaks of the Raja of Chandragiri, the Damarla brothers Venkatappa and Aiyappa. They wanted

the new settlement to be named as Chennapatnam after his father Chennappa Nayak. Chennai started with a land cover of 69.9 Sq kms in 1871 and the expansion was very slow during the pre-independence era. However Chennai grew at a very fast rate after independence especially in the last two decades. Chennai city has grown by 1,683% in about one and a half centuries.

Gardens of Chennai

Dr. James Anderson started the first Botanical Garden at Madras in 1769. Starting his botanical researches in 1771, he established a Nopalry (*Nopalea cochenellifera)* in Saidapet, its location in today's terms along the western edge of Mount Road from approximately the Long Tank Drain to the Saidapet Bridge. By 1791, it had been developed as a botanical garden, the first in India, and flourished till 1800. Anderson, meanwhile, had developed between 1778 and 1792 his private botanical gardens in the 111 acres around his house in Nungambakkam, bound by College Road, Graeme's Road, Graeme's Lane and Haddow's Road. Anderson's Gardens survived till at least 1828, long after his death, which pioneered the development of botanical gardens in India (Raman, 2011).

Chennai and its neighbourhood had several groves of economically important species such as tamarind grove, mango grove and jack grove. The names of certain places in Chennai are synonymous to the word grove for example *Palathope* (jack grove) in Mylapore, *Pulianthope* (tamarind grove) in Perambur, *Maanthope* (mango grove) in Ambattur, Chennai. There were a number of gardens established by rich people as well as by colonial rulers especially on the banks of the Coovum (Muthiah, 2008). The British started the culture of parks in Chennai. The first park that was established in Chennai is the My Lady's Park adjacent to the present central railway station. Subsequently parks were established in T-Nagar, Mylapore and in other places.

Ecosystem services of urban parks

The urban parks apart from providing green and open space for recreational purposes also provide a number of ecosystem services. Ecosystem services are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza *et al.* 1997). According to Bolund and Hunhammar (1999), trees in urban areas offer a variety of ecosystem services like air and water purification, rain water recharge, noise filtering, health, microclimate stabilization and biodiversity conservation**.**

Rain Water Recharge

The trees in the urban forests or the vegetated area help in retaining the rain water upto 70- 80% by reducing the force of the rain water which falls directly on the surface and running off into the storm water drains. In the cities without vegetation 60% of the rain water goes through the storm water drains (Bernatzky, 1983).

Health

According to recent studies the presence of trees in human neighbourhoods helps in overcoming

several psychosocial problems (Kuo, 2003). Parks or gardens with trees are used for morning and evening walks, exercises and recreation by all kinds of people (Photo 10). A study in 9 cities of Sweden shows that people of all categories, professions and age consider parks, gardens and urban forests as the most effective means for stress relieving and relaxation (Grahn, and Stigsdotter, 2003). A study undertaken in Guangzhou, China indicates that more than 50% of its residents use urban forests for recreational and stress relieving purposes (Jim and Chen, 2006).

Air Pollution

Vegetation plays a major role in reducing air pollution; however the level of reduction depends on the local conditions. The major constituent of air pollutant is the Suspended Particulate Matter (SPM). Urban parks having more canopy cover can filter the particulate matter thereby improving the quality of air (Givoni, 1991).

Micro climate

The concrete structures in the urban areas absorb the sun's energy and radiate the heat to the ambient air making the area hotter by several degrees. This phenomenon is termed as heat island. This heat is reduced by the evapo-transpiration process of the urban green spaces (Shashua-Bar *et al,* 2010).

Noise

In urban areas noise levels from traffic and other sources are high creating health problems to people. Vegetation and open green spaces reduce the intensity of noise levels (Bolund and Hunhammar, 1999).

Biodiversity

Green space is one component of biodiversity management and the most obvious. Biodiversity is the living diversity of nature. Trees in cities and towns, in parks and gardens provide a wealth of benefits relating to biodiversity. Urban parks support a great variety of wildlife and are the only refuge to certain birds, squirrels, insects, butterflies, bats and bees. Some of these insects and birds are the important pollinators (Mendes et al. 2008). Even the trees in backyard provide the benefit of biodiversity conservation networks in urban ecosystems (Hillary *et al.* 2002). In spite of the ecological and environmental importance, the parks have not been studied adequately in most parts of the world. (Cornelis and Hermy, 2004; Davies *et al.* 2008; Weifeng *et al.* 2006; Clarke *et al.* 2008), in contrast to the importance paid on parks in forested areas (Nagendra, 2008).

This lack of understanding of biodiversity distributions and dynamics in urban parks makes it very difficult to plan strategies for urban conservation (Alvey, 2006; Weifeng *et al.* 2006; Jim and Chen, 2009). Extensive research on urban forestry including urban parks has been carried out in North America and Europe, in comparison to few studies from other parts of the world (Fernandez-Juricic and Jokimaki, 2001). The few studies conducted in the Asia/Pacific have also largely focused on Australia, South-East Asia and Russia (Jim and Liu, 2001;

McKinney, 2008), with very little information on urban forests and specifically on urban parks in South Asia (Nagendra and Gopal, 2010; Singh *et al.* 2010).

Conclusion

As per WHO norms, the green space per person in a city should be at least 9.5 sq.metres. The green space in cities includes wide variety of greeneries namely avenues, urban forests and parks. In majority of the cities in India, with a few exceptions the urban forest concept is poorly implemented. However the considerable percentage of green space is contributed by parks. Per capita green space data available for selected cities indicates that Ahmadabad and Chennai have far below values than the recommended space by WHO (Table 3).

In this trend of urbanisation, parks being the green spaces and lungs of the cities are the need of the hour. The urban parks apart from providing green and open space for recreational purposes also provide a number of ecosystem services. The urban area in Chennai has rapidly increased in the last 40 years, an average increase of 25 Sq. Km per year. However, the increase of green space in the form of parks was far from adequate.

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Table. 3 Some Indian Cities with per capita Green Space

Name of The City	Population in million (Census 2011)	Forest and Tree cover (Km^2)*	Per Capita Green Space (m^2/inhabitant)
Bengaluru	8.43	150	17.79
Chandigarh	1.02	17	16.6
Delhi	10.9	129	11.83
Ahmadabad	6.35	21.8	3.43
Chennai	8.91	12.84	1.44

(Source: http://www.censusindia.gov.in/2011;*ISFR, 2019)

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ALTERNATIVE / CLEANER FUELS

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Abstract

A growing number of countries believe that alternative fuels have a significant role in the present and the future. This is due to lower vehicle emissions, sustainability and energy-independence. As always, there are a few pros and cons in case of alternative fuels. Alternative fuels are clean and widely available in many countries. Designing the engine in a specific way makes lowering emissions much easier. Fuel-cell vehicles run on electricity produced through an electrochemical reaction, a highly efficient process, producing electricity without combustion or pollution. At the same time, there are negative impacts –e.g., Natural gas production produces more methane; subsidy for ethanol production has impact on food prices; Most of the electricity is generated from coal or natural gas; Electric vehicles are the only hope for a greener future. Use of biodiesel, plant-based fuel such as lemon-peel oil, water-hyacinth biodiesel, microbial fuel cell, soap-derived biokerosene are some of the promising alternative fuels, which are currently in research.

Key words: alternative fuels, biodiesel, biohydrogen, ethanol blended petrol, biomass conversion, plant based fuels.

Introduction

Alternative fuels are derived from sources other than petroleum. Most are produced domestically, reducing our dependence on imported oil, and some are derived from renewable sources. Often, they produce less pollution than petrol or diesel. These are usually substances other than conventional fuels such as fossil fuels, nuclear materials such as uranium, thorium etc. Some of the well-known alternative fuels include plant-based diesel, refuse-derived fuel, batteries, fuel cells, non-fossil methane, non-fossil natural gas, vegetable oil and fuels from biomass sources. India is one of the major oil importing countries (almost 80% of the requirements is met by importing). Presently, India's transport sector accounts for about 6.7% of India's Gross Domestic Product (GDP) and diesel is used in about 72% of the transportation sector, petrol in 23% and the remaining usage comprises

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other fuels such as Compressed Natural Gas, Liquid Petroleum Gas etc. The alternative fuels provide the best option to replace the traditional fossils and provide opportunities for reducing the import of oil bill, mitigation of pollution, and can be produced sustainably. Moreover, India with plentiful natural renewable energy resources can exploit them for achieving the economic and social development in an environmentally compatible manner (SIAM Report, 2019).

Why alternative fuels?

World Health Organisation has estimated that more than 90% of rural households in India rely on the use of solid biomass fuel such as cow dung cake, firewood, crop residues, twigs etc. for cooking and heating purposes. Use of solid biomass fuels have disadvantages such as laborious and time consuming collection, transfer-drying-stacking followed by combustion (partial or incomplete combustion leads to toxic pollutants such as particulate matter, carbon monoxide and polycyclic aromatic hydrocarbons) (Ravindra *et al.,* 2019). To cater the ever increasing energy demand, alternative fuels such as ethanol and refuse-derived fuel must be used. Some reasons for use of alternative fuels are:

- Fossil fuels are non-renewable
- Reduction of pollution
- To protect against global warming
- Affordable, use of waste as reuse
- Fuel economy, ease of production and use; biofuels, on one hand reduces pollution, and on the other hand helps farmers (Belyh, 2015).

Domestic production of alternative fuels

Ethanol is produced domestically from corn and other crops. It produces less greenhouse gas (GHG) emissions than gasoline or diesel.

Electricity is produced domestically from a variety of sources such as coal, natural gas, nuclear power, and renewables. Powering vehicles with electricity causes no tailpipe emissions, but generating electricity can produce pollutants and green house gases.

Biodiesel is diesel derived from vegetable oils and animal fats. It usually produces less air pollutants than petroleum-based diesel.

Natural gas is a fossil fuel that is plentiful in the U.S. It produces less air pollutants and Green House Gases than gasoline.

Propane, also called liquefied petroleum gas (LPG), is a domestically abundant fossil fuel. It produces less harmful air pollutants and GHGs than gasoline.

Hydrogen can be produced domestically from fossil fuels (such as coal), nuclear power, or renewable resources, such as hydropower. Fuel cell vehicles powered by pure hydrogen emit no harmful air pollutants (United State Environmental Protection Agency).

CLEANER FUELS

Biohydrogen from food waste fermentation: Three different mechanisms have been proposed in

the literature for the production of biohydrogen: photolysis of water by algae, dark fermentation during the acidogenic phase of anaerobic digestion (hybrid biogas and biohydrogen), and two-stage dark/photo fermentation (Kapdan and Kargi, 2006). At present, most hydrogen is commercially produced by steam reforming of methane in natural gas, often extracted by hydro-fracking operations. Biohydrogen production is an attractive alternative to demand for fossil natural gas, since many species of bacteria have the capability to produce hydrogen via fermentation of a broad range of organic feedstocks.

The following table gives the fermentation type and the type of food waste used for production of hydrogen:

Food waste	Fermentation
Canteen waste	Batch fermentation
	Combined solid- state and dark fermentation
Tofu processing waste water	Continuous fermentation with sewage sludge inoculum
	Anaerobic fermentation using mixed microbial culture
Apple waste, apple pomace	Batch fermentation, Anaerobic fermentation
Cheese whey	Continuous dark fermentation under thermophilic conditions
Waste bread	Continuous anaerobic fermentation using sludge
Mixed fruit peel waste	Continuous fermentation using up-flow anaerobic contact filter
Pineapple waste	Anaerobic mixed culture fermentation

Source: Hegde and Trabold (2018)

Bioethanol: Bioethanol has been identified as a clean fuel that is mixed with petrol to run automobiles without modifying the engine design. Bioethanol does not produce SO_2 or NO_2. In 2004, logen (Canada) became the first company to produce 1 million gallons per year of cellulosic ethanol from wheat straw at a plant in Ottawa (Doble and Kruthiventi, 2007).

Treatment of Natural Gas

Dimethyl Ether of Polyethylene Glycol has been used in gasification projects to selectively remove CO_2 from the synthesis gas, to produce a clean fuel for integrated gasification combined cycle (IGCC) power plants. In these plants where the syngas feed to the DEPG process is unshifted (without converting CO to CO_2 and hydrogen), a single-stage DEPG unit can be used (Mokhatab, Poe and Mak, 2019).

Shale Gas

Nonconventional shale gas or oil will have a much better market in the

next decade. In a global scenario of economic growth and huge energy demand in the next decade and also in consideration of the environmental issues, shale gas is going to replace the main source of energy. Demand of shale gas will increase as the technology for the shale gas exploration improves. With the large reserve of 6609 TCF of shale gas globally and the demand of 106 TCF per annum, the existing reserve will provide energy for the next 60 years (Dayal, 2017).

Nuclear Hydrogen Production

It is a flexible, clean fuel and can be produced by a variety of methods, stored, and transported. Its use ranges from refining crude oil, forming fertilizer, direct electricity generation, and other hosts of industries. Nuclear energy has enabled large-scale production of hydrogen without any greenhouse gas emission or pollution. A key future challenge for hydrogen as a clean energy carrier is a sustainable, low-cost method of producing it in large capacities. Most of the world's hydrogen, about 97%, is currently derived from fossil fuels through some type of reforming process such as steam-methane reforming. Nuclear hydrogen production is an emerging and promising alternative to steam-methane reforming for carbon-free hydrogen production in the future (Revankar, 2019).

BIOFUELS

First Generation biofuels – Made from food crops; sugar, starch or vegetable oil obtained from crops is converted into biodiesel or ethanol using transesterification or yeast fermentation (Biofuels Digest, 2010).

Second Generation biofuels – Made from lignocellulosic biomass or woody crops, agricultural residues or waste plant material; byproducts of agricultural harvest – extra water or fertilizer is required. Non-human food sources such as grass, jatropha and other seed crops, waste vegetable oil, municipal solid waste etc. No arable land is required. But, fuel extraction is a difficult process (Jerome and Thomas, 2015).

Third Generation biofuels – Use of oil rich algae; extraction of algae from system and processing into biofuels with the dried products re-processed for production of ethanol. High yield, algaculture does not require farmland or freshwater. Extraction of biofuel lipids from wet algae using ionic liquids had already been demonstrated (Teixeria, 2012).

Fourth Generation biofuels – Made from non-arable land. It does not require destruction of biomass. These includes electrofuels and photobiological solar fuels. Some of these are carbon-neutral (Biofuels Digest, 2010).

Ethanol blended Petrol

It is a type of alcohol found in alcoholic beverages, used as fuel. It is most often used as a motor fuel, mainly as a biofuel additive for petrol. Ethanol is commonly made from biomass such as corn or sugarcane. World ethanol production for transport fuel tripled

between 2000 and 2007 from 17×10^9 litres to more than 52×10^9 litres. Ethanol fuel has a "gasoline gallon equivalency" (GGE) value of 1.5, i.e. to replace the energy of 1 volume of gasoline, 1.5 times the volume of ethanol is needed. It is made by the catalytic hydration of ethylene with sulphuric acid as the catalyst. It can also be obtained via ethylene or acetylene, from calcium carbide, coal, oil gas, and other sources (Alternative Fuels Data Centre – Fuel Properties Comparison, 2014, World Fuel Ethanol Analysis and Outlook, 2016).

The Government through Oil Marketing Companies (OMCs), is implementing the Ethanol Blended Petrol (EBP) Programme under which, OMCs sell ethanol blended petrol with a percentage of ethanol upto 10%. In order to augment the supply of ethanol, the Government in 2014, decided to procure ethanol produced from other non-food feedstock besides molasses, like cellulosic and lingo cellulosic materials including petrochemical route. If a sugar mill produces ethanol with a combination of B heavy molasses (a type of heavy molasses) and sugarcane juice, the ethanol price derived from B heavy molasses route shall be payable by OMCs. The average blend percentage was 4.19% (as of 2019) which is the highest in the history of EBP Programme (Ministry of Petroleum and Natural Gas report, 2018 – 19).

Second Generation (2G) Ethanol

The availability of conventional biofuels i.e.1G ethanol and palm Stearin/ non-edible oil seeds based biodiesel is limited. With the recent initiatives such as widening of feedstock base for ethanol production, scheme of augmenting capacity and exploring Used Cooking Oil (UCO) for Biodiesel production, this figure may increase up to a maximum of 450- 500 crore litres by 2022 which will still be very less as compared to the targets envisaged under National Policy on Biofuels-2018.

Compressed Biogas (CBG)

Biogas is produced through a process of anaerobic decomposition from waste / biomass sources like agriculture residue, cattle dung, sugarcane press mud, municipal solid waste, sewage treatment plant waste, etc. After purification, it is compressed and called Compressed Bio-Gas (CBG) which has more than 90 % methane content. Further, CBG has properties similar to the commercially available natural gas and can be used as an alternative, renewable automotive fuel (National Policy report, 2018).

Benefits

- Responsible waste management, reduction in carbon emissions and pollution
- Additional revenue source for farmers
- Boost to entrepreneurship, rural economy and employment
- Support to national commitments in achieving climate change goals Reduction in import of natural gas and crude oil
- Buffer against crude oil/gas price fluctuations.

Biomass conversion

A variety of feedstock, including cellulosic biomass (the fibrous and inedible portions of plants), algae, wet waste, and biogas can be used. The use of a specific feedstock or feedstock blend will depend on the conversion process. Feedstock for primarily biochemical processes are selected for optimum composition, quality, and size and may include agricultural residues, woody residues, grasses, or blends of these three. The elevated temperatures of thermochemical deconstruction (300°C to 1,000°C) expand the range of biomass feedstock that can be used by the bioindustry. High-temperature deconstruction encompasses pyrolysis, hydrothermal liquefaction, and gasification.

Pyrolysis is the thermal and chemical decomposition of feedstock without the introduction of oxygen to produce a bio-oil intermediate. The bio-oil produced contains hydrocarbons of various lengths but contains more oxygenated compounds than petroleum crude oils and must undergo up-grading before it can be finished into a fuel or used in a refinery. *Hydrothermal Liquefaction* is a deconstruction process that utilizes a wet feedstock slurry under-elevated temperature and pressure to produce a hydrothermal liquefaction bio-oil. The feedstock is treated with water before entering the reactor and is particularly applicable to algal feedstock. Nonwater solvents may also be used.

Gasification is the thermal decon-struction of biomass at high temperature (typically >700°C) in the pres-ence of substoichiometric air or an oxygen carrier and sometimes steam, followed by gas cleanup and condi-tioning.

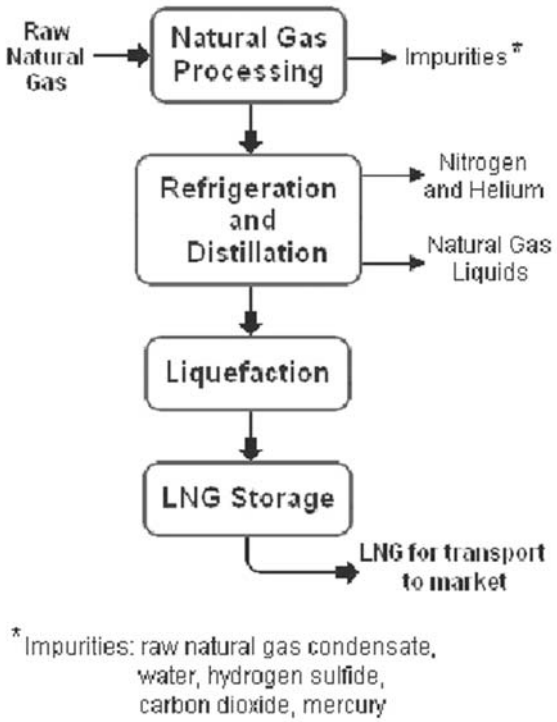
Intermediates produced following deconstruction can include crude bio-oils, sugars, gaseous mixtures, and other chemical building blocks. These intermediates are upgraded using various techniques to produce a finished product. Microorganisms can ferment sugar or gaseous intermediates into fuel blend stocks and chemicals. Alternatively, sugars and other intermediate streams such as bio-oil and synthetic gas may be processed catalytically to minimize the effect of reactive compounds to improve storage and handling properties.

The finished products from upgrading may be fuels or bioproducts ready to sell into the commercial market or stabilized intermediates suitable for finishing in a petroleum refinery or chemical manufacturing plant (Biomass Conversion, US Department of Energy, DOE BETO)

Liquified Natural Gas (LNG)

LNG is a clear, colourless and non-toxic liquid which forms when natural gas is cooled to -162°C (-260°F). The cooling process shrinks the volume of the gas 600 times, making it easier and safer to store and ship. In its liquid state, LNG will not ignite. LNG is primarily used to transport natural gas from one source to another. Exporters use this method when shipping to different countries and across bodies of water when pipelines are not available. The

gas produced from hydrocarbon deposits typically contains a wide range of hydrocarbon products, which usually includes methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). All these products have wide-ranging boiling points and also different heating values allowing different routes to commercialization and also different uses. The "acidic" elements such as hydrogen sulphide (H_2S) and carbon dioxide (CO_2), together with oil, mud, water, and mercury, are removed from the gas to deliver a clean sweetened stream of gas. Failure to remove such acidic molecules, mercury, and other impurities could result in damage to the equipment. Corrosion of steel pipes and amalgamization of mercury to aluminium within cryogenic heat exchangers could cause expensive damage.



Source: Beychok (2007)

Other plant-based fuels

Lemon peel oil has been reported to show very similar calorific value, stoichiometric air to fuel ratio as isooctane, an ideal reference fuel for a gasoline engine, and also possesses very good anti-knock tendency and octane number rating (RON ¼ 80) making it a possible alternative fuel for petrol engines (Biswal *et al.,* 2019).

Soap-derived Biokerosene (SBK) production for alternative aviation fuel has been reported. Production of SBK involves two processes: saponification and thermal decarboxylation to convert coconut oil into hydrocarbons. Also it was reported that SBK is feasible for use as a drop-in aviation fuel when blended with conventional jet fuel (Duong *et al.,* 2020).

Application of **Microbial Fuel Cell (MFC)** is coming to the forefront as a dual-purpose system for wastewater treatment and energy recovery. Future research should emphasize on developing low-cost field-scale MFCs for removal of organic matter, nutrients, xenobiotic and recalcitrant compounds from wastewaters and powering low energy devices. Biochar is a carbon rich solid material, which is produced via slow and fast pyrolysis, gasification, etc. Three products may form during the gasification or the pyrolysis of organic precursor namely biochar, biooil, and syngas (Chakraborty *et al.,* 2020).

Use of **fuel slurries** based on pulverized wood (saw dust), agricultural straw and household cardboard waste were studied and reported that about 43% of coal and oil can be saved. Also,

lower ignition costs were reported while using a mixture based on straw, cardboard and oil additives (Vershinina *et al.,* 2020).

Water hyacinth biodiesel, when blended with diesel fuel at proper concentrations can yield a neat diesel fuel in terms of thermal efficiency. However higher emissions of CO_2 and NO_x is also present. It can be a viable biofuel for diesel engine (Alagu *et al.,* 2019).

Direct application of **corn-oil** as biofuel may consume large energy. But alternative fuel blends containing corn-oil and methanol and ethanol can be used to improve the solubility of blends (Zhang *et al.,* 2020).

Alternative **diesohol fuel (diesel / bioethanol)** with 15% bioethanol and **distilled cashew nut shell liquid** can comparatively reduce environmental pollution and is an economically superior choice than fossil fuels (Suwanmanee *et al.,* 2020).

Use of **corncob** for co-production of hydrogen and methane in an anaerobic digestion process can yield around 13% of **bio-hythane** (hydrogen concentration) with an energy conversion efficiency of 27% (Zhang *et al.,* 2020).

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EARLY ECOLOGICAL KNOWLEDGE OF ANCIENT INDIAN PEOPLE

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Abstract

This article deals with early ecological knowledge that can be gleaned from the ancient Indian scriptures. The early Indian religious texts such as the Vedas, Upanishads, Arayanyakas, Epics, Puranas and the entire classical Sanskrit literature are the basis of our understanding of the conservation, preservation and management of forests of ancient India. Ancient Indian texts like the Arthasastra, Sathapatha Bhramana, Manusmrti, Brhat-Samhita, Ramayana, Mahabharatam and Rajtarangini mirrored the ideas of forest ecology and conservation. Sacred gardens are associated with ancient traditions in several major cultures, as well as Hinduism. Sacred groves are patches of natural vegetation demarcated by ancient societies and guarded on the premise of non-secular practices and cultural traditions. Ancient Indian people knew the importance of resource conservation, protection of sacred groves, sacred trees, medicinal plant species, etc. At the time of Sanskrit literature, thick forests abounded in India.

Key words: Forest conservation; ecological knowledge; sacred groves, environment.

Introduction

In India, there is a long and ancient tradition of reverence for nature right from Vedic times. Different cultures react to nature differently and have different perceptions of ecological knowledge. Traditional ecological knowledge includes the world view or religious customs of a society. Therefore, traditional ecological knowledge may be defined as the sub-set of indigenous knowledge handed down over the generations by the indigenous people. Indigenous knowledge includes many fields such as traditional medicine and agriculture and ethnobiology. Many times, traditional ecological knowledge overlaps with cultural ecology, ecological anthropology or anthropological ecology (Berkes et al., 2000). Traditional ecological knowledge is embedded in a culture and has a large social context. This article proposes to discuss certain aspects of the ecological knowledge of ancient Indians.

Forests have formed an inseparable part of nature since the beginning of

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life on earth. In India, the land was covered with thick and dense forests in ancient times. Ancient Indian culture and religion displayed great reverence for nature and all that it represented. Nature worship was an intrinsic part of the Vedic religion.

The Islamic sultanate was established in north India around 1200 CE. The sultans began to clear the forests and encourage and the growth of agriculture. The sultans also began to regard the forest as a source of revenue.

The Mughal emperors continued the policy of the Delhi Sultans. They also reserved large areas of forest for their private hunting pleasure. It can fairly be said that both the Delhi sultans and the Mughal Emperors had no laid down policy for the preservation and conservation of forests. During the Mughal period there was a steady rise in the area under cultivation and this involved the felling of forests.

With the advent of British rule in India, there was a perceptible change in the official policy towards forests. British and Indian timber merchants felled many forests in Uttarakhand, Himachal Pradesh and Kashmir. Commercial interest even did not spare the pristine forests of Assam, Manipur and Nagaland. Since the forests are now owned by the people of India, the government has undertaken several legislations in the 1950s and 1960s to protect the forest cover and also the *fauna that resides therein (*A History of Ancient and Early Medieval India, 2008*).*

Ecological knowledge of the pre-historic period

The Ghaggar-Hakra river has since been identified with the lost river Sarasvati (Danino, 2010), making the Indus Valley culture into an Indus-Sarasvati culture. The discovery of Mehrgarh, one of the earliest sites with evidence of farming and herding in South Asia, suggests that the modification of the environment – from forest to agriculture – had begun very early in north-west India (now Pakistan). The Indus valley civilization was primarily urban.

History of forest jurisprudence in India

Since the dawn of history, early man worshipped and feared the forest since they considered them the abode of the gods. The sacred forests are scattered throughout the country and even today, the indigenous people worship them. Some have destroyed the forests and some have preserved them. Recent studies have shown that there were dense forests in India during the Permian period, 250 million years ago. At that time, India was covered with thick forests, except Rajasthan and parts of Punjab, which were buried under the swamp of the remnant of receding Tethys Sea (Sagreiya, 2000, p.2).

Ancient Thoughts

There are many references to the principles of forest conservation in ancient literature such as the Vedas. These can be dated to roughly 3000 BCE

to 1800 BCE. The concern for the environment and resource management extended upto the post Vedic and Puranic times (200 BCE – 100 CE). Vedic religion also emphasises the oneness of man and nature and this was reflected in various rituals and practices (http://www.haryana- online.com/History/vedic_culture.htm; last accessed on twelve Feb 2019; 8000–1000 BC eds.,).

Vedic Period

Ancient India witnessed a close symbiotic relationship between people and nature. The Rig Veda says: "Do not cut trees because they remove pollution" (RV 6: 48:17). The Atharva Veda (12:1:27) says "We invoke the all supporting earth on which trees, Lords of forests, stand ever firm". In the Virat Parva (5.45-46) of the Mahabharata, it is said "Do not destroy the forests with tigers and do not make the forest devoid of tigers. Forests cannot be saved without tigers and tigers cannot live without the forests because the forests protect the tigers and the tigers protect the forests".

Rivers, forests, animals, and the sun were considered worthy of worship. According to Samkhya philosophy, ecology is an integral part of human existence. However, Hindu sages realized that for sustainable development, preservation of nature was essential (Suresh Basrur, 2012)./ hinduism-and-environment.php).

Ancient Indian literature is replete with references to different aspects of environment, its management, preservation and protection. The Vedic, Puranic, Jain and Buddhist traditions established the principles of ecological harmony centuries ago. India is not only divided in culture, religion, social customs, language, dress and food habits but also in climate, environment, flora and fauna (Benudhar Patra, 2016, pp.39-56). The Harappans were familiar with several methods to control and preserve water for irrigation (Jha, 2003, p.34).

The subject of forestry tradition is well covered in the Aranyakas and the Upanishads known as 'Brhadaranyaka' (Great Forest Text). The literal meaning of aranyaka is "produced by or relating to the forest" or "belonging to the forest". The aranyakas were composed by sages living in the forests. According to the Vedic philosophy, forests represent the feminine principle or prakriti.

The Rig Veda says that plants are even older than the gods. It is possible that the Rig Vedic people knew that plants have life. The plants existed on earth before the creation of animals (Rig Veda, 10.97.1). There is also verse in the Rig Veda which says categorically that forests should not be destroyed (8.1.13). "Plants and herbs destroy poisons (pollutants)" (Atharva Veda, 8.7.10). Thus it is apparent that the Vedic people had established a clear relationship between nature and man's place in it. A verse from the Rig Veda says `Thousands and hundreds of years if you want to enjoy the fruits and happiness of life, then take up systematic planting of trees (Pathak, et.al., 2012).

"Brihadaranyaka Upanishad" (3.9.28) equates trees with human beings.

Nature conservation in ancient India

For example, the Atharva Veda (Chand, D. (Tr.). 1997, pp.949) reads: "O Earth! Pleasant be thy hills, snow-clad mountains and forests; O numerous coloured, firm and protected Earth!

Community conserved forest (CCF) -Sacred groves

Sacred groves are patches of natural vegetation demarcated by ancient societies and protected on the basis of religious practices and cultural traditions. Sites such as woods, forests, rivers, streams, rocks, mountains, peaks and trees equated to ancestral spirits or deities are found throughout the world. At the dawn of religious thinking, deities were imagined by primitive societies to reside in stones, trees, animals and woods. This worship of nature reflects the respect and gratitude that the ancient Indians had for nature for sustaining them. They exemplify the perceived interlink between man and his natural environment as well as his ecological prudence (Gadgil and Vartak, 1975, pp. 623–47), provide a cultural identity to each community, represent native vegetation in a natural or near-natural state, thereby contributing to biodiversity and environmental conservation (Bhagwat, 2006, pp.519–524).

In India, there is an ancient tradition of preserving nature by deifying it and according it an honoured place in religious tradition. The various cultural connections are expressed through myths and religious practices that celebrate plants and animals, forests, rivers, mountains and precincts that are so essential for existence. The concept of the sacred in nature has protected a section of India's biological diversity in a fast-changing world.

Tree Worship

Tree worship is an ancient and national phenomenon in India. The sanctity of the sacred tree is attributed to either the place or the temple. The trees that were sanctified reveal the socio-economic-health concerns of ancient peoples. Tree worship is found in all ancient societies across the world. The sacred tree had many names: kalpavriksha (tree of life), chaityavriksha (tree shrine) or sthalavriksha (tree of the sacred site). Ancient people worshipped trees because trees represented fertility and divinity and their worship would enable people to invoke divine blessings. If trees were worshipped, then the resident spirits were pleased. The tree thus represented an important economic entity. The primary function of the tree was to shelter the deity. Thereafter, the tree which had once sheltered the deity became the sacred tree of the temple; the tree was associated with the deity and became an inseparable part of the local mythology.

Down the ages and widespread across India, the tradition of placing trees on a pedestal, the village trees, or fenced in as the sacred trees was a popular practice. The ashvatha or pipal was obviously a tree of great

importance. A seal from Mohenjo-Daro shows a bull protecting an Acacia tree. This figure must be the spirit or yaksha of the tree not unlike the yaksha concealed within the tree in later art. The figure within the tree on the Indus seals fits this description perfectly. The pipal tree or ashvatha (Ficus religiosa) is mentioned in the Rig Veda. The sanctity of the pipal tree was thus affirmed by Vedic literature. While ashvattha have been identified as the sacred fig tree or Ficus religiosa, plaksha, the fig tree and another species of Ficus has also been identified with the pipal.

Two major religions, namely Jainism and Buddhism developed in ancient India during the 6th century BCE. Especially, Jainism preached the doctrine of ahimsa which was non killing of all living creatures like animals and plants. It is also worthy to note that both Mahavira and Buddha attained enlightenment under the pipal tree (Aswatha vriksha) known as the bodhi tree. The twenty four Tirthankaras also preached respect for nature and tolerance towards animals.

Buddhist traditions attribute Gautama's enlightenment to his meditation under the pipal tree, which was his Bodhi tree or the tree of enlightenment. The sculptures of Bharhut, Sanchi and elsewhere are replete with sacred trees which are fenced in where the tree represents the Buddha, while temples all over India are illustrated with sculptures of chaitya vrikshas - trees protecting the deity beneath. The trees on the seals are the earliest examples of a long tradition of tree worship that continues till this day. Sacred trees are generally associated with Shiva, Vishnu, Skanda and sometimes with the goddess Shakthi. They are also found associated with some village guardian deities, such as Arkamma (erukku/ Madar), Panaiveriyamman (panai/ Indian Palm), Puliyidaivalaiyamman (puli/Tamarind) and Kadamberiyamman (kadamba/ common bur flower tree).

Sacred groves in Sanskrit Literature

Sacred groves once existed in most parts of India. According to Gadgil and Vartak (1975, pp. 623–47) there is a historical link between the sacred groves and the pre-agricultural, hunting and gathering stage of human evolution. Hence the concept of virgin forest is believed to be of pre-vedic origin, that is over 5000 years ago.

Nature worship dates back to the Vedic period (5000 BCE) and is based on the premise that all creations of nature have to be protected. Also, other species and patches of forests are preserved in the name of local deities. An important tradition of nature worship was to protect patches of forest dedicated to deities or ancestral spirits and manifested the spiritual and ecological ethos of local indigenous communities. Atharva Veda (12.1.11) hymns are believed to have been composed around 800 BCE, somewhere amidst deep forests, read:

Patches of vegetation were preserved as amara vana, venu vana, sala vana, ashoka vana, kadamba vana, vilva vana etc. and were named after the dominant / characteristic species

(Somashekar, 1998, pp.3-7). Early Buddhist literature reflects the agrarian landscape of the period. Around the grama (village) or suburban area lay the pasture or khetta, its forests where the people gathered their regular biomass requirements, and its primeval uncleared forests like nanda vana of Kosala, sita vana of Magadha, etc., which were retreats haunted by wild beasts and forests spirits (Rapson, 1935) just as most sacred groves are the abodes of spiritual deities even today.

The Hindu scriptures do highlight the importance of planting trees and groves of trees. For instance the Vriksotsavavidhi of the Matsya purana attaches great importance to the planting of trees and even to the celebration of the tree festival. The same Purana states: "A son is equal to ten deep reservoirs of water and a tree planted is equal to ten sons". Other dharmsastras also prescribe the planting of trees: "Just as a good son saves his family, so a tree laden with flowers and fruits saves its owner from falling into hell, and one who plants five mango trees does not go to hell" (Kane, 1958).

The etymology of the word vana means forests which could also mean sacred forest. Sita was kept captive in the ashokavana, or forest of Saraca indica, by Ravana. This beautiful small tree is a sacred tree of India and grows in the shade of humid tropical evergreen forests. The authors have seen the ashoka tree growing in many vanas (bana in Kannada) which are sacred to the people of Uttara Kannada (Karve, 1974; Gadgil and Guha, 1992) state that the introduction of iron in India about 1000 BC was instrumental in the march of agriculture and pastoralism into the forest-covered Gangetic valley. The destruction of forests with their wild animals amounted to weakening the resource base of the food gatherers.

Sacred Groves in Sangam literature

It appears that the ancient deities of Tamil Nadu are the present deities worshipped in villages under different names. The goddess Kotraivai also called as Kotri was said to be living in the forest in the midst of devils. There is a reference to this in Sangam literature like Kalithogai.

The woods, forests and deserts were considered as the temple of Durga and accordingly worshipped. Durga is also known as Kaanamar selvi, i.e., Goddess of the Forest ('Kaanamarselviyirulavin' – Akanaaruru – 345). Some of the forests were also named after this Goddess. One such forest was Vindaadavi or Forest of Vindai, another name for Goddess Durga ('Kadavutpeyariya-kanamodu' – Pathitrupattu – 88).

In the Tamil epic Silappadikaram, we come to know that the Chola port city of Poompuhar had a number of groves like ilavandigaisolai. (Which means campathi bird resided in the campathy forest (vana); Kaveranaang's lived in the kavera forest (vana) ....)

One can find temples at places like Poompuhar, Tiruvenkadu, Talachan-kadu, Perunthottam, etc., The Pattinappaalai describes the land and the people of the seaport of Poompuhar. Similar depictions are also available

regarding the other great cities like Madurai, Vanji, Kanchi and sacred temple towns like Srirangam.

The history of the Kolli hills is closely linked with ancient Tamil literature. It is believed that in the Ramayana, these hills were called "madhuvanam" (forest of honey), the abode of the monkey king, Sugreva. The Kollipavai temple is located in one of the 15 sacred groves here and can be approached only on foot (Arunachalam, 2009,pp. 1-15).

There is an ancient temple in the Kolli hills dedicated to Lord Arapaleeswarar on the Aiyaru stream. Cemponpalli, Tevankuti cirappalli tenkur; Cowell Kollik cold 'araippalli' (6-70-1); Karappalli,Tirukkattuppalli; Kamal killer 'araippalli' (6-71-1) in praise of Lord Shiva had sung in praise of Lord Arapaleeswarar Appar mentions this temple in his Thevaram in praise of Lord Shiva between 7th and 8th CE. This temple is held in high regard by the tribes of this region.

Siddhas are saints in India, mostly Shiva worshippers in Tamil Nadu who possessed and practiced unorthodox forms of spiritual practices to attain liberation. Historically, Siddha also refers to the people who were early age wandering adepts that dominated ancient Tamil teaching and philosophy. The sacred groves are guarded by the local temple deities and the felling of trees is prohibited. The surrounding places of the temple of Arapaleeswarar and the sacred grove regions in the hills are still held in reverence.

The groves associated with ancient temples were called Nandha vanas during medieval South India. There have been found several inscriptions which referred to the grant of land by ancient kings for the purpose of maintenance of temple gardens called Tirunandavana. Great varieties of flowering plants are being cultivated and flowers from these gardens are offered to the deity to perform pujas.

Nanditha Krishna (2002) recounts an inscription of the 10th century CE belonging to the period of the Chola King Raja Raja I. It refers to a temple of Kaalar, the squadron leader of Aiyanar's army. Raja Raja the Great donated lands, paddy for pongal and land for the maintenance of the Pidari and Ayyankovilkadugal (SI, Vol.II. p.56). The villagers were allowed to enter the grove and worship the deities only on the condition that they should not harm the animals and plants. Another festival, "Thiruvettai or sacred hunt" is described in an inscription of the Chola King, Raja Raja II.

They were of five types of groves in medieval Tamil Nadu viz. (i) exclusive floral gardens, (ii) groves of fruit bearing trees (orchards), (iii) gardens having flower and fruit bearing plants, (iv) groves having only one type of plant (Thoppul Thottam) They were maintained by the priest(s) or village committees as evident from an epigraph of the Chola king, Kulothunga III.

Harihara II (1388 CE), donated land to the Thirumullaiudayanayanar for the hunting festival. Inscriptions belonging to Devarayha II dated 1424 CE found on the south wall of the central shrine in the Masilamaniswarar

temple at Tirumullaivoyil, Saidapet taluk, Chingleput district of Tamil Nadu mention that the King Orri-Mannan alias Udaiyar Orri-Arasar and Arasuperumal alias Kadavaraya (Devaraya II) gifted 4000 kuli of land for conducting certain special festivals in the Kadavarayartiruttoppu (sacred grove) and at the Asangadagandan-mandapa in the temple of Tirumullaivayal-udaiya-nayanar.

Nandavana (Sacred Gardens)

Nandavana (forests of pleasure) or temple gardens were groves associated with ancient temples during the medieval period in south India. Several inscriptions refer to the grant of land by rulers to maintain temple gardens called Thirunandavanam. Many varieties of flowering plants were cultivated and flowers from these gardens were offered to the deity to perform puja. Sacred gardens are an ancient tradition in many major cultures, including Hinduism. Although, there is less archaeological evidence of early gardens in India, Hindu scriptures and books like the Ramayana, Abijnana Shakuntalam, Mrichchakatika, etc. give remarkably detailed description of elaborate gardens with flowerbeds, lotus ponds, fruit trees, creepers and shady spaces. In the Bhagavad Gita, Krishna praised the trees of Brindavan: "They have dedicated their lives to the welfare of others.

There are many stories in Vedic literature which showed the interactions between worldly persons and sages in their forest ashramas. The beauty of natural creation was called in Sanskrit vanavaibhava. It could be argued that the romanticisation of the forest began when it was thought that culture was suppressing nature. In ancient times, the last part of a man's life was known as Banaprastha and Sanyas wherein he retired to the forests to discover his self.

Types of sacred gardens

Most Hindu temples have associated gardens known as nandavanam, with which the divine leelas of the deity are associated.

Lord Buddha was born under a tree in the Lumbini garden (in Nepal), which is now listed as a World Heritage Site, and gave his first sermon at the gardens and played a central part of the life in the monasteries during the early periods. Several stupas, ruins of ancient monasteries and temples and gardens are among the prominent attractions in Sarnath. The recreated garden has lotus pools and a sacred bodhi or pipal tree, grown from a sapling of the original bodhi tree at Bodhgaya under which the Buddha attained enlightenment.

The temples of Ranakpur are situated in the Pali district of Rajasthan. The temples are situated within an enclosure which is treated as a garden. There is a 600 year-old sacred tree in the main temple courtyard. So trees are never cut down to build a temple.

The temple is surrounded by a garden with a variety of flowers, fountains, and a reservoir with colourful fish swimming on the surface of the glistening water.

Bagh (bagicha) are ethno-silvi-horticultural gardens, traditionally planted near tanks, settlements or amidst forests, especially in north India. The gardens mainly consist of utility trees such as Mangifera indica, Madhuca latifolia, Syzygium cuminii, etc. Green felling is totally banned in these gardens. Also, there is a temple or separate space dedicated to the deity.

The goddess Padmavathi or Alamelumanga temple at Tiruchanur maintains a garden, with many varieties of jasmine and other fragrant plants, covering 4.0 hectares is dedicated to goddess Padmavati. Ornamental, landscape and flower gardens occupy an area of 460 acres in Tirupati and Tirumala, managed by the Tirumala Tirupati Devasthanam (TTD), containing about 200 varities of different plants. Some inscriptions which can be dated to the 14th and 15th centuries CE refer to many flower gardens. There are also many tanks and ponds such as Alwar tank, Mangalabhavi and Ananthapalligunta which are useful not only as perennial water sources for the temple gardens but also for growing lotus flowers.

Melkote in Pandavapurataluk of Mandya district is a sacred Vaishnava pilgrimage site in Karnataka. Here, a garden dedicated to Sri Narayana-swami, covering 6.0 hectares has about 27 varieties of jasmine and a number of unusual plants. Odisha has several sacred gardens: Ekamravan garden, Gundicha temple garden, Hanuman vatika, Raja Rani temple garden, and Rani Sati temple garden are a few. The garden house of Jagannath, the Gundicha temple stands in the centre of a beautiful garden with coconut, mango, neem and bael trees and the favourite flowering plants of Krishna's association with gardens has resulted in many being named "Brindavan", the Madanagopalaswamy temple in Madurai, Tamil Nadu.

In the famous Sriranganatha Swami temple at Srirangam in Tiruchirapalli, there is a sacred garden also called nandavana comprising of 4.05 hectares and dedicated to Lord Sri Ranganatha. The garden has an orchard where every tree is named after an Alvar, a Vaishnava saint of the Tamil tradition. The world-famous Meenakshi Amman temple, also in Madurai, has a nandavanam where flowers are grown to be offered to the deity (Krishna, Nanditha, 2017, pp. 63-71).

Forestry in the later Vedic period

According to Vedic tradition, every village should have certain categories of forests. Mahavanis considering the great natural forests, which may be equivalent to the protected forests of today. Shrivan may be considered the production forests, which provide the ecological services and goods to both humans and animals. Tapovan is the forest of religion and is sacred as the home of the sages. No animal or tree should be harmed in these forests since they are reserved for the practice of religion.

Herbs and plants having union with sunrays offer a congenial atmosphere forever to survive (Atharva Veda, 5.28.5). 'Brihadaranyaka Upanishad' (3.9.28) equates trees with human beings:

rather like a tree, the blue blood of the forest…"

During the Vedic period, each village had its own panchayat, which maintained a forest in its own territory (Prime, 2002, pp. 157). The later Vedic period also saw a significant shift from cattle rearing to agriculture (1000 BCE – 500 BCE).

At the time of the *Ramayana,* thick forests abounded in *Naimisharanya,* Chitrakoot, Dhandakaranya and Panchavati. The *Kishkindha* Kanda of the Ramayana discusses the geography and forestry, *Balakanda* mentions about the plants and a thickly forested region on the far bank of the river Ganga. The plants are classified into economic, sacred and utilitarian. There are also mentions of some of the medicinal plants. The *Ramayana* covers the vast geographical area of the sub-continent and hence numerous species of plants found mentioned. The area covers three major ecosystems, namely, the tropical deciduous forest, the alpine region semi forests (Himalayan) and the evergreen tropical forests of Sri Lanka (Roy, Mira, 2005,pp. 9 – 29).

The *Ramayana* describes in detail the types of forest found during the exile of Rama and Sita. Chitrakoot and Dandakaranya can be called the principal forest, whereas Panchavati and *Nilalkanana* can be described as belonging to the stretch of the principal forest, the so called sub-forest. The forests contained mainly deciduous plants and waterbodies are also mentioned. There is an extensive description of the Chitrakoot forest. It is also known as the Mahavana or great forest. The forest comprising of beautiful flowering trees surrounds it on all sides. The Aranyakanda of the Ramayana describes the ashrams as *"aranyaiscamahavrksaihpunyaihsved uphalairvrtam"* which means abounding in tall forest trees, sacred trees and in sweet fruit-bearing trees (2.1.5). Finally, there is mention of the evergreen forests of Lanka. The naturalized forests are beautifully described as *ashokavana,* named after the predominant species found in Ravana's private grove (5. 2.6; 5.2.9-11; 5.14.3-4, 5.7-8.26). In the Lankan evergreen forests, the predominant species appears to be the Asoka tree (David Lee, 2001,pp. 260-61).

Sacred Plants in the Ramayana

According to the Ramayana, there were several types of sacred trees: the *rathyavriksha* or roadside trees (II, 3.18, 50.8; V. 12.18, 22-29) and the *devatanishthanavrikshas,* which were the abodes of deities. These were further divided into the *yakshachaitya* (the yaksha's tree shrine) and *vrikshachaitya* (tree shrine). The Ramayana is replete with descriptions of trees and their uses. Sita, on her way to the forest, worshipped and circumambulated a large banyan tree on the banks of the river Kalindi, entreating it to enable her husband to fulfill his vow (Agrawala, 1970). The forest of Dandakaranya where Rama, Lakshmana and Sita lived and the grove of Asoka trees where Sita was imprisoned in Lanka are still sacred. The Valmiki Ramayana mentions this tree in many places as the "Ashoka Vatika" that is the garden of ashoka trees. There were strict injunctions

against the felling of trees in Lanka. The *Ramayana* states that even during the reign of Ravana, the planting of trees was considered a worthy objective. The *Ramayana* make several references to the worship of sacred plants and trees like the tulsi, pipal, banyan and Indian gooseberry. Banyan was the tree of Panchavati (3.13.21), a model of majesty to which Sita compared Rama himself (3.47.34). The Ramayana describes the *sleshmaataka* (Indian cherry) *vana,* i.e., the forest of *sleshmaataka* trees found around *Gokarna* where once Shiva was concealed as a stag. When Rama and Lakshmana were scouring the forest for Sita, they came across a *badari* tree. They asked the tree whether perchance it had seen Sita. Rama often compared the *campaka* flowers to Sita's neck (3.60.32).

Economical plants in the Ramayana

Punnaga was a valuable garden tree and its flowers yielded scented materials (5.10.23). Six poles of *bilva* tree were erected as sacrificial posts (1.4.22). The fruit was edible (2.94.8); it was one of the trees used for bridge construction (6.22.55). The Arjuna tree, during the rains, exudes a pleasant fragrance (4.30.25). Giant Arjuna trees were used in bridge construction (6.22.56). The charming wild cinchona tree found in abundance in the Chitrakuta forest (2.94.9) bore flowers that scent the whole forest (4.28.41).The bamboo is mentioned as a common forest tree (6.12.56) found growing on the banks of the river Yamuna (2.55.8). The Indian mesquite is a large tree in the Panchavati forest (3.15.18); its spreading branches were used to make the roof of Rama's cottage at Panchavati (3.15.22). It is also where Lakshmana tells Rama of the arrival of Bharata's chariot, bearing a flag with the emblem of the *kovidara* tree.

Cultural importance of the plants

The deodar is worshipped as a divine tree. The sages preferred this type of forest to perform penance. However, the Sanskrit literature mentions this forest as *'Darukavana'*. For example, in the *Kishkinda* Kanda of the Valmiki Ramayana mention is made of Rama instructing his followers to search for Sita with Ravana in the forests covered by *lodhra* trees, *Padmaka* trees and in the woods of *devadaru* or *devadaru* trees (4.43.13). The tree finds mention in the Ramayana as the *ashokavana* (grove of ashoka tree) in Lanka. It is then decorated with a small garland of flowers and twigs of the neem tree. The sandal tree is used as a cosmetic anointment with *aguru* (2.15.33). It is a tree of Panchavati (3.15.18).

In the *Mahabharata*, there are many references to forests. During the period of their exile, the Pandavas spent a lot of time in the forest. The area around modern Delhi was thickly forested at that time. According to Buddhist tradition, the Buddha attained enlightenment under the pipal tree. India of that time contained many patches of vegetation comprising of *amaravana, venuvana, salavana, ashokavana, kadambavana, vilvavana,* etc. named after the dominant tree species (Somashekar, 1998, pp.3-7). The uncleared forests were known as *nandhavana* of Kosala and sita *vana* of Magadha (Rapson, 1935).

India during the time of Mauryas contained many thick and luxurious forests (*Arthasastra,* II.1.20).

Forest is the vital part of nature and its conservation and sustainable management help people and animal to live in healthy ecological atmosphere. In the Mauryan Empire of Chandragupta, forest was state property and its use had to be undertaken by state officials. There was a separate department headed by a head *samaharta,* a kind of collector, with several subordinate officers under a superintendent of the forest whose duty was to look after every matter related to the forest (*Arthashastra*, II.6.1-2), collect and process forest produce like timber, fruits, fibres, medicine etc., fix the price and sell it at the proper time. He was responsible for providing water and irrigation facilities to the forest during draught and other seasons. The superintendent of the forest could impose penalties on erring officers and anti-social persons misusing the forest produce or destroying the vegetation. The *samaharta* had to collect the revenue derived from forest produce and trade and increase the economy of the state (*Arthashastra*, II.6.28). The result was the luxurious growth of the forests all over the sub-continent during Kautilyan times. The forest management system, like everything else in the *Arthashastra*, had an excellent set of checks and balances.

The *Arthashastra* describes four kinds of forests: forests of deer (*mrigavana,* economic forests (*dravyavana*), elephant forests (*hastivana*), bird sanctuaries (*pakshivana*) and forests of wildlife (*pasuvana* and *vyalavata*), the last. The *dravyavana* is a source of forest produce, while the *hastivana* was a sanctuary for elephants. Kautilya also mentioned that the *Brahmaranya* (forest where the Brahmins can continue their studies of the Vedas and other scriptures; *Somaranya* (forest fit for carrying out religious sacrificial rites); Deforestation and illicit tree felling was punished by a levy (*deya*) and a fine (*atyaya*). Ecological balance was maintained as there was a state of environmental awareness. The *goruta* or *krosha* is an artificial forest with single entrance, surrounded by a moat, encompassed by a canal, having trees without thistles and a few trees bearing sweet organic products; it contains shallow pools of water, wandering deer and different creatures, wild creatures having their hooks and teeth expelled, and male and female elephants alongside their whelps (AS.2.2.3). Kautilya encourages the King to build up a few backwoods, one each for the different timberland produce (*dravyavana*) for example, every huge wood was to contain the gathering of an extraordinary kind of tree, for example, mango, or *shala*, and so forth and furthermore timberlands for plants for creating merchandise from trees and furthermore backwoods for verifying different woodlands objects (AS.2.2.5).

The state also reserved pasture land which was gifted to Brahmans which was planted with various species of trees and shrubs. There are also reserve forests filled with wild animals for the king's hunting pleasure.

Thus, the forest evolved from the place of spiritual retreat in the Vedic period to a place of exile in the *Ramayana*. During the period of *Mahabharata,* the process of urbanisation led to destruction of the forests. Finally, during the Mauryan period the forests were well protected since it was seen as a source of revenue.

The Buddhists also regarded the forest as the place of retreat where the Buddhist monks lived in *chaityas* and *viharas* along the Western Ghats. Kalidasa's *Abhijnana Sakuntalam*, there is a reference to the importance of forests and preservation of wildlife and the symbiotic relationship between people and the forests through *ashrama* life. There is also redolent description of prancing deer and singing birds, of flowers in bloom and leafy creepers evokes an image of an idyllic forest rich in plant and animal life.

Medicinal plants

Right from Vedic times, the mighty Himalayas were known as a vast laboratory of medicinal plants and other natural resources. The Emperor Ashoka planted many medicinal herbs and trees besides shade giving trees along the highways and fruit bearing trees in the wastelands.

Traditional medicine

Jangala was the region of open space where a steady dry wind blew. The common plants of the region were *khadira* (*Acaciacatechu*), *asana* (*Terminalia tomentosa*) and *badari* (*Zizyphusjujuba*).

The common plants were mandara or *parijataka* (coral tree) and *santana* (*kalpa* tree) (Majumdar 1978).

Other works were also composed during these periods.

Unani, Rasashastra, Siddha and Sa-Rigpa Traditions

The *Siddha* custom is an antiquated south Indian framework that grew particularly in the Tamil speaking districts.

Regional Folk Practices

Prior to the development of *ayurveda*, folk medicines were practiced in various parts of the country. The indigenous people developed their own systems of medicines by accessing the herbs and shrubs in the forests. There were also specialists in bloodletting, experts in physical medical practices and others with intimate knowledge of medicinal plants. It may also be mentioned that certain healing plants were also worshipped by the indigenous people. The material medica of traditional medicine has drawn heavily upon the tribal medical traditions which in turn depends upon the forests for their needs. Along streets I have had wells burrowed and trees planted to serve people and creatures." There is a practice in certain areas that before a tree is cut, the spirit of the tree is asked for forgiveness by chanting certain mantras. The convention of purifying different trees and plants predominant during the Vedic time frame additionally may have helped their safeguarding.

It may be seen that Indian religious literature is filled with ideas of forest conservation, utilization, and regeneration. The traditional conservation ethos is also strengthened in a variety of practices that support biodiversity conservation in natural ecosystems and helps reduce the harvest pressure. In Tamil Nadu, many archaeological sites pertaining to Megalithic culture (5th century BCE) have been discovered. The Sangam age belong to the period from 2nd century BCE to 2nd century CE; approximately, it was associated with many literary works such as *Tolkappiyam, Silappadikaram, Manimekhalai, Pattupattu,* etc.

Classification of Land in south India

Tamils had shown their relationship between the land, ecology and religion. The five-fold classification of Tamil land (*thinais* otherwise known as eco-zones of modern ecological classification of the land) is described in the *Tolkappiam*. The five thinai or the eco zones and each of which used to have a special tree, a animal, a bird, a flower and a deity. In *Neithal* or the coastal lands have their specialized plants such as kandal and punnai and the birds of this region were the marine crow, swan, crane, heron etc. The *paalai* flower (silvery leafed plants) and wild vegetation grew here. In the modern state of Kerala (ancient Chera Nadu), Kaali / Durgai temples face north. Characteristic plants of this landscape are the Paalai tree (Wild sapota / Manilkara hexandra), *marul* (Indian bowstring hemp / *Sansevieria roxburghiana* and *sappathikalli* (Cacti). The term Palai refers to the dry land region. *Silappadikaram* states that the dry lands of *Kurinji* and *Mullai* became *Palai* (*Kaadukaan Kaathai* II: 60-67). During the Sangam period, people were practicing their customary activities like hunting, gathering, cultivating and worshipping deities. The goddess Kotraivai also called as *Kotri* was said to be living in the forest in the midst of devils. The woods, forests and deserts were considered as the temple of Durga and accordingly worshipped. Durga is also known as *Kaanamar* Selvi, i.e., Goddess of the Forest (*"Kaanamarselviyirulavin" – Akanaanuru* – 345). Some of the forests were also named after this goddess. One such forest was *Vindaadavi* or Forest of Vindai, another name for goddess Durga (*"Kadavutpeyariya-kanamodu" – Pathitrupattu* – 88) (SubramaniaPillai, 1948).

The way of life and lifestyle of the old Tamils were profoundly entwined with trees, foliage and blooms. On special occasions, the kings of ancient Tamilagam decorated themselves with particular flowers: the Cheras with *pondhai / panampoo* (flowers of the Indian Palm tree), the Cholas with *aathi* (*Capparis zeylanica*) and the Pandyas with *vembu* (neem tree).

Seasonal behaviour like flowering, producing new leaves, or shedding of flowers and leaves was taken as an indication of future happenings. This tree was revered by devotees for its unfailing prophetic attributes. The king in times of war, appealed to this tree to bloom in emerald verdure as a token of victory to the king (*Purapporul Vennpamalai,* 243). The lord revered that

tree and a sound and solid tree spoke to the ruler and his standard. Comparative reference is made to commend the triumph of Imayavaramban Neduncheralathan over the *Kadambargal* by cutting the *kadamba* tree which was their kaavalmaram (protecting tree or tutelary tree). The introduction of iron during the later Vedic period saw the development of agriculture in the forested Gangetic valley (Karve, 1974; Gadgil, and Guha, 1992). The destruction of forests and wildlife weakened the resource base of the food gatherers who lived in those forests. During the wandering in the forest, the Pandavas came across many sages living in ashrams, for example that of sage Kanva.

On the other hand the *Puranas* emphasise the planting of trees and regeneration of the forests. For instance, the *Varaha Purana* (172.39) says that "One who plants a pipal, a neem, a banyan, two pomegranates, two oranges, five mango trees and ten flowering plants or The practice of *"vanamahotsava"* (tree plantation ceremony) is an ancient tradition. *Agni Purana* says that the plantation of trees and creations of gardens leads to the eradication of sin (Dutt 1903, sloka162). A close reading of the Puranas shows a great concern for environment, flora and fauna. They conceptualized the trees to feel happiness and sorrow (Vidyasagara, (ed.), 1876, p. 231)[62] and attributed auspiciousness to plantation of trees (*Skanda Purana:* 1.2.27, 21-22; *Agni Purana* 2 Vols, Calcutta, pp. 282. 1-4).

In the *Padma Purana* (56.40-41), the cutting of a green tree is an offence punishable in hell.

Sacred trees, groves, and landscapes

The Hindu concept is that the whole world is the forest. 'To keep this world as it is we have to keep the world-forest intact' (Kumar, pp.299–306). It also established the concept of cultural landscape such as sacred forests or groves and corridors. They also practice a variety of ethnoforestry practices. These reflected the ecosystem like concepts in traditional societies' (Berkes, et.al., 1998, pp.409–415). Examples of these are the temple forests, the forests of the monasteries, consecrated trees, sacred forests/grove and sacred trees (Ramakrishnan et al., 1998, p.480). However, it is possible that "the Vedic people borrowed the ideas of environmental values and the concept of 'sacred groves' from the indigenous people who lived in north India during that period.

The laws of Manu called the *Manusmriti* (200BCE -200 CE) were composed during this period. This text has also condemned cruelty towards animals. The later Vedic period marked the transition from pastoralism to settled agriculture. This would necessarily have involved the cutting down of forests in the Gangetic plains. It is possible that the Vedic people assimilated new environmental values and the concept of sacred forest from the pre-Vedic people who inhabited the northern part of the subcontinent at that time (Ramakrishnan, et.al., 1998, pp.480).

The Gupta dynasty re-established political stability and brought a large part of north India under its control.

However, due to increasing urbanisation there was significant destruction of forest cover. Political stability was restored only during the time of Harshavardhan (606 CE to 647 CE) (Lal, 1989, p. 17). From the description, we can conclude that the region of the Vindhya mountains was thickly forested at that time.

South India during this period was ruled by the powerful Chola kingdom with its headquarters at Thanjavur. There is enough evidence to show that the Chola kings took a keen interest in the management of water and forests. They undertook vast irrigational activities, built canals and bridges and planted shady trees for the benefit of the people. It is evident that the ancient Indian kings took a benevolent attitude towards nature and took concrete steps to preserve and protect it (Das, Shukla, 2003, XXI: 129-141).

Ecological knowledge on irrigation system

The most notable feature of this period was the spread of rice cultivation adopting irrigation methods. Tribal communities, namely Irulas, Malayalis and Muthuvans living in the state of Tamil Nadu, have been cultivating traditional cultivars of paddy, millets, pulses and vegetables. Selection of a place with good hydrologic potential to locate the tank should also ensure economy in construction cost. Sangam literature makes elaborate references to the location of tank, tank construction and water lifting devices, sluices, gates and channels.

A poem from Purananuru written by Kudapulavianar exhorts the king to create tanks wherever there are land depressions conducive to storing rain water. The tanks were generally not dug but created by forming bunds to hold water in a sloping terrain or encompassing a depression on plain grounds.

Some of the irrigation structures outlined in Sangam literature are still in vogue and are a historical evidence of indigenous irrigation technology.

Sangam literature makes elaborate references to the location of the reservoir, its construction, and water lifting devices, sluices, gates and channels. A poem from *Purananuru* (18), written by Kutapulaviyanar exhorts the king to create tanks for storing rain water wherever there are land depressions. Irrigation tanks were constructed by kings, ministers, landlords, village communities, temple authorities and private individuals.

Ecological knowledge includes forests, knowledge of wildlife, domesticated animals, agriculture, water conservation, irrigation techniques, construction of tanks and waterbodies, and so on. The Vedas, Ithihasas, Epics, Puranas, Canons of Buddhists and Jains have recorded different kinds of thickly forested vanas. The ancient Indian people knew the importance of traditional knowledge regarding resource conservation, protection of sacred groves, trees, medicinal plants, etc. Subsequent to the development of civilisation and settled agricultural life, the forests were subjected to cutting and deforestation. Officials were appointed to collect taxes and

punish those who violated the forest laws of Kautilya. In the Sangam age came the classification of land and the practice of settled agriculture, customs and culture.

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