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REVIEW ARTICLE

Integrating indigenous knowledge in modern agriculture: Challenges and opportunities

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Abstract

Around 10000 years ago, humans began domesticating plants and understanding the role of weather and soil in agriculture. Over generations, they developed environmentally friendly farming practices, that sustained productivity while preserving local ecosystems. This historical perspective underscores the value of indigenous knowledge in developing alternative resource management approaches. Traditional techniques, refined through centuries, hold immense significance and must be safeguarded from extinction. These methods are eco-friendly and community-centric, offering viable solutions to contemporary agricultural challenges, including climate change, resource depletion and food insecurity. Their low-cost, sustainable nature makes them an essential complement to modern high-input farming. Integrating these practices with contemporary agriculture can foster resilient, environmentally sound and culturally significant farming systems. However, to fully leverage their potential, further research scientific validation and systematic documentation are imperative. Research institutions, NGOs and policymakers must collaborate to revive, adapt and disseminate these techniques among farming communities. This synergy between traditional wisdom and modern innovation can bridge the gap, ensuring a more sustainable agricultural future. By recognizing, validating and integrating traditional agricultural knowledge, we can create robust farming systems that preserve biodiversity, improve resilience and support food security for future generations.

Keywords

climate change; indigenous knowledge; resource management; sustainable agriculture

Introduction

Indian agriculture is at least 10000 years old, as evidenced by the agricultural practices referenced in the Rig Veda (c. 8000 BC), which shows the early development of farming techniques. Animals were domesticated and utilized for various purposes. New crops and the agronomic knowledge associated with them were being added to farming over the millennia (1). Today, India grows a very large number of crops because of the availability of diverse agro-ecological conditions. Throughout this period, until the advent of modern agriculture in the last two centuries, farmers, with advice from sages, developed and fine-tuned crop production technologies. Almost all farm activities were based on the availability of local material and human resources. In other words, there was hardly any need to "purchase" external inputs.

During British rule, India's agriculture faced significant challenges due to insecurity, interference with land ownership systems and the emphasis on Europeanizing Indian agriculture. Farmers carried on with their own traditional agriculture only halfheartedly. When India became independent, its food security was minimal. This led to regular annual import of food. Food security is a basic prerequisite for the self-respect of any country. Since the Green Revolution was based on high-input, intensive agriculture, we ran into problems such as the erosion of resources and the neglect of resource-poor farmers. If the resource-poor farmers are to raise their living standards, they will need to learn highly efficient techniques that depend on locally available, low-cost input. The knowledge gained during ancient and medieval periods can benefit resource-poor farmers today, especially those who depend on rainfall alone as source of water. We must acknowledge George Watt, a British botanist, who compiled traditional agricultural techniques in his multi-volume work 'Economic Products of India' (1889-1893), a significant contribution to documenting Indian farming practices (2). From his books, we can get a glimpse of the practices followed by farmers of the Indian subcontinent in the 19th century. After a long gap, interest in documenting traditional agricultural practices rose as the ill effects of the Green Revolution became evident. The Indian Council of Agriculture recently documented currently used traditional practices (3).

This review reveals many ancient and medieval agricultural techniques that had been forgotten over the years but are highly useful and cost effective today.

Methodology

This review paper follows a systematic approach to collect, analyse and synthesize relevant literature on the revitalization of indigenous knowledge in contemporary agriculture. The search strategy involved the use of relevant keywords such as "indigenous knowledge in agriculture," "traditional farming practices", "sustainable agriculture", "climate resilience through indigenous knowledge" and "integration of traditional and modern farming techniques". To ensure a balanced and rigorous selection of studies, we established specific inclusion and exclusion criteria. Studies published from 2000 onwards in peer-reviewed journals, conference proceedings and institutional reports were prioritized, focusing on the role of indigenous knowledge in modern agricultural systems. Articles that lacked empirical evidence, were not in English, or focused solely on historical perspectives without addressing contemporary applications were excluded.

Further, qualitative content analysis was employed to categorize the findings into key themes such as challenges in indigenous knowledge adoption, opportunities for integration, policy implications. Case studies highlighting successful implementations were also included. The synthesis of findings was guided by a thematic approach, ensuring a structured and coherent discussion.

Results and Discussions

1. ITK in Agricultural Meteorology and Rainfall

Human being (*Homo sapiens*) has been on the earth for approximately 2 million years. Humankind has been a hunter-gatherer for 99.5 % of his existence and this period is considered as most successful. Only 10000 years ago, humankind started domesticating plants and recognized weather and soil as the most precious natural resources (4). So, humankind managed environments where he lived for generations by following environmentally friendly agricultural practices without significantly damaging local ecologies. This forms a strong basis to believe that indigenous knowledge may provide a powerful basis from which alternative ways of managing resources. This indigenous knowledge can be made as in the last 200 years of scientific agriculture there has been an over-exploitation of natural resources.

Rainfall Prediction by astrology

The science of Astrology originated from the understanding of seasons and weather patterns based on the movements of planets. All cultures and civilizations have developed a form of Astrology among which the Indian system is "Luni-solar" based, in which the main activity is the time reckoning and calendar computations (5). In terms of weather forecasts, two important aspects are as follows:

a) The onset of rain is linked to the wind direction and

b) Seasonal rainfall is linked to phases of the Moon, constellations, other planets, etc., in cycles. Astronomical calculations can predict rainfall for any number of years, as the positions of planets are predetermined. Table 1 shows us different types of clouds and based on dominance of a particular type in a year the rainfall is predicted.

Table 1. Different types of clouds and based on dominance of a particular type in a year the rainfall is predicted.

S.No.	Type of cloud	If dominant in a year
1.	Abartak	Rain will be received in certain places in that year.
2.	Sambartak	Rain will be received in all parts of the country.
3.	Pushkara	Rainfall quantity will be less.
4.	Drona	Abundantrain water.

Panchanga

In India, the classical Hindu Almanac is known as "Panchanga". It is a book or record of astronomical phenomena containing a calendar of days, weeks and months of the year. Weather prognostications and seasonal suggestions for a state or country are often mentioned (6). It acts as an astronomical guide to farmers to start any farming activity. Panchanga making might be traced from Vedic Literature more so during the Vedang Jyothish period (1400 - 1300 BC). However, handwritten Panchanga of the early 17th century and later periods are available in some Indian libraries.

The word "Panchanga" is derived from Sanskrit language in which there are several ways through which rainfall is predicted by Panchanga. Of them a few prominent are panch means five and "ang" which means body parts. The five arts of Panchanga are:

1) Lunar day (30 days in one month).

2) Week (7 days)

3) Asterium (constellation) (Twenty-seven).

4) Time (The twenty-seven number of times). Joint motion of the Sun and Moon covers the space of asterium.

5) Halfday.

Added to these five arts planets, solar months and year; Lunar month and year, etc., are mentioned. The permanent relationship is established among all the five arts solar months, planets, Asteriums, etc., and printed in the form of a guide every year. This is useful to practice agriculture and other weather-related activities by the farmers.

2. Ancient methods of rainfall prediction

Agriculture in India is not an occupation. It is a way of life where 70 % of its total cultivated area depends on rainfall for assured crop yields. So, the prosperity of the Nation and success of agriculture depends on favorable weather and climate, especially rainfall. In better decision making at planning and operational levels and to minimize some unfavorable effects of weather and climate the role of rainfall forecasting is enormous. Ancient Indian farmers have developed rainfall forecasting techniques through generations of living in close contact with nature, with their intellectual knowledge and spiritual wisdom. Such techniques are classified based on

a) Astrology

b) Biological indicators

c) Atmospheric conditions

3. Traditional agricultural practices for crop production

In ancient days and prior to the Green Revolution, farmers in rural areas were practicing a wide range of traditional techniques for pest and disease control. Some practices were supplemented with religious ceremonies and rituals. A few examples are given below.

- The festival ***Karthigai Deepam*** is celebrated during the months of November–December wherein there is community lighting of lamps during the evening hours. This serves as a bonfire for the pests that attack the samba crop (sown in Aug–Sept) that will be at its peak vegetative phase during this period (Nov–Dec) and is highly prone to pest attack.

- ***Mulaipaari*** (germination test) is done in the month of *Adi* (July). People in the villages take a handful of seeds of the different varieties of crops that they are interested in sowing that season and place them in a pot for germination. This is left in a temple for four to seven days after which the pot is carried round the temple. The seeds that have germinated better are chosen for sowing in the following season. This serves as a germination test for different seeds (7).

- ***Pon yerukattuthal*** is done on the first day of *Chitirai* (which usually falls on April 14th). The *yeru* (plough*)* is worshipped, decorated and taken to the field where the first ploughing is done. This incidentally falls during the peak of summer and this summer ploughing brings the resting stages of pests like pupa to the surface where they are destroyed either by the hot sun or are picked up by predatory birds.

Many such practices are on the verge of extinction owing to the Green Revolution and the quest for increasing food production to meet the demands of the growing population. However, these traditional methods are simple, cost-effective, eco-friendly and can easily be adopted by farmers (8).

They can be broadly grouped as follows:

1. **Mechanical methods** involve the mechanical removal of pests. For example, hand-picking the larvae and grubs, removing eggs from the tips of the leaves by pinching off the terminal portion, warding off birds that damage grains using effigies or by producing noise using drums, controlling pests by dusting ash on the plants etc (9).

2. **Agronomical methods** include various methods like intercropping, trap cropping, border cropping, crop rotation, fumigation, use of light traps, use of bird perches, etc (10).

3. **Biological methods** involve the use of parasites, predators, botanical pesticides, etc. for crop protection (11). Some of the well-known examples for the biological agents used to prevent the infestation of pests are Ladybugs (Coccinellidae), Lacewings (Chrysopidae) and Parasitic wasps (e.g., *Trichogramma spp*.) are some of the well-known insects used in the prevention of pests in plants in general.

4. Traditional technologies:

i) ***Use of bonfire (light trap)****:* Light traps can be used to monitor and trap adult pests thereby reducing their population. Some common forms of light traps used are bonfires (traditional method), electric bulbs and hurricane lamps. A large plate or vessel containing kerosene mixed with water is placed near the light. The light trap should be 2-3 feet above the crop canopy. The trap should be set up in the field between 6-9 pm. After 9 pm, there are chances of beneficial insects getting trapped. Adult moths, which are attracted by the bright light, fall into this water and die (12).

ii) ***Bird perch****:* The birds perch method involves the use of certain structures that invite birds to the fields when the larval population is high T-shaped bird perches can be erected in the field at the rate of 15-20 per acre. Turmeric powder mixed with rice canal so be place don't he perches to attract the birds. They should be one foot above the crop canopy. These perches serve as resting places for the birds that feed upon the larvae in the fields (13).

iii) ***Intercrops/trap crops/border crop****:* Trap crops are plants that attract pests away from the main crop, serving as a natural pest management strategy. These plants lure pests by being more appealing than the primary crop, effectively concentrating infestations in a controlled area where they can be removed or treated. Some trap crops also disrupt pest lifecycles or attract beneficial insects like predatory wasps and ladybugs, which help control pest populations. For example, mustard or radish can protect cabbage from flea beetles, marigolds deter nematodes while attracting aphid predators and sunflowers draw stink bugs away from tomatoes and peppers. This approach reduces the need for chemical pesticides, lowers production costs, improves crop yield and promotes sustainable agriculture by enhancing biodiversity and natural pest control mechanisms. This crop will invite the pests and thereby the main crop can be saved largely from pest infestation (14).

iv) ***Fumigation***: Fumigation is the traditional method in which the smoke from certain natural products is used to control diseases, especially in vegetable crops and to ward off pests in storage godowns. Fumigation is the process of application of gas, vapor, or smoke to seeds and plants for the purpose of disinfecting or destroying pests. Generally, fumigation is done in storage areas and in the fields. Sweet flag (*Acoruscalamus*), vaividangam (*Embeliaribes)* and turmeric (*Curcuma longa*) are a few of the natural products commonly used for fumigation (15).

5. Use of botanicals & biopesticides

Neem kernel extract: One acre of land requires 3-5 kg of neem kernels. The outer seed coat should be removed before use. The kernels should be pounded gently and placed in an earthen pot to which 10 liters of water should be added (16). The mouth of the pot should be tied with a cloth and the pot should be kept aside for three days and then the contents should be filtered. On filtering, 6-7 liters of extract can be obtained. The shelf-life of this is about one month. Three to eight-month-old seeds should be used (17).

Neem cake extracts: One acre of land requires 5 kg of neem cake. The neem cake should be powdered well placed in a cotton cloth and tied. This should be immersed in a vessel containing 10 liters of water for three days. Later, the pouch should be squeezed well into the water. About 7-8 liters of the extract can be obtained (18).

Examples of plants used as biopesticides are given in Table 2. Examples of a few promising biopesticides are given in Table 3.

6. Indigenous Seed Storage Structure

A proper seed storage facility is crucial as seeds are the primary genetic link between generations of a plant species. Storage in warehouses is greatly affected by external environmental factors. Seeds should be stored in such a manner that their germination capacity and vigor should not decline. In temperate regions, seeds can be stored under ambient conditions for longer periods. However, in tropical and sub-tropical regions, parameters such as temperature and moisture need to be controlled to preserve the seed vigour. Up to 30 % of seeds are lost during storage due to insects, rodents and microorganisms (19).

The storage period begins right at the time of attainment of the physiological maturity of seeds in the field till it is planted in the next season. Care should be taken to preserve the germination capacity, viability and vigour of the seeds. Storage in warehouses is greatly affected by external environmental factors. All other stages should be monitored and care should be taken to ensure the physical purity, germination viability and vigour of the seeds (20). Examples of various moisture content of different crops are given in Table 4.

Seeds should be dried to an optimum moisture level, less than 12 % for starchy seeds and less than 9 % for oily seeds. Seeds should be cleaned thoroughly and should be free from trash, insect and microbial damage. If the relative humidity is low or maintainable, then the seeds can be stored in paper envelopes. Storage containers should be cost-effective, air-tight and have low thermal conductivity. Storage containers should be moisture-proof which include sealed tins or aluminum cans, glass jars with gasket lids (21). Natural products used in storage pest control are listed below

i. Neem products in pest control

- Collect the required amount of neem, Pongamia and vitex leaves, then shade dry them until they become papery. Fill the storage bin up to three-quarters and cover the seeds with a clean cloth. Mix the dried leaves and spread a handful on the surface of the seeds in the storage bag or bin. This method can also be followed in bigger storage containers. Neem oil can be mixed with the seeds at the rate of 2 % by the weight of the seed. Using oil is more effective than the

Table 2. Examples of plants used as biopesticides

Common Name	Scientific Name
Adhatoda	*Adhatoda zeylanica*
Asafoetida	*Ferula asafetida*
Chilli	*Capsicumannuum*
Sida	*Sidaacuta*
Garlic	*Allium sativum*
Ginger	*Zingiberofficinale*
MilkWeed	*Calotropis gigantean*

Table 4. Maximum moisture content of various crops

Crop	Maximum moisture content
Millets	12%
Paddy	13%
Cowpea	9%
Pulses	9%
Maize and Sorghum	12%

Table 3. Examples of a few promising biopesticides

Name of the preparation	Crops tested	Effective against
Adhatoda, *pudhina, triphalakashayam*	Paddy, vegetables	Leaf folder, bacterial leaf blight, Helminthosporium leaf spot
Andrographis and sida *kashayam*	Vegetables	Aphids and borersin brinjal And okra
Barley, sesamum, horse gram *kashayam*	Vegetables	Acts as a yield enhancer
Cows urine and sweet flag *arkam*	Paddy, okra, chillies	Bacterial leaf blight, *Helminthosporium* leaf spot, vein clearing, fusarial wilt, ripe rot
Garlic *arkam*	Paddy	Leaff older, bacterial leaf blight, Helminthosporium leaf spot
Panchagavyam	All cops	Growth promoter and Provides resistance against diseases
Need seed extract	All crops	Leaf folder, aphids, jassids, Fruit borer and stem borer
Five leaf extract	All crops	Jassids and borers
Ginger, garlic, chilli extract	All crops	Hopper sand borers

leaves.

- Seeds can be stored by mixing with neem oil (2-3 mL/kg of seed). 50 kg gunny bags of any seeds need 150 mL of the oil for mixing (22).
- Neem seed powder can be mixed at the rate of 1 % to the volume of the seed. This is practiced for the control of khapra beetles, rice weevils, etc. which are found in storage (23).
- Mix 30 g of ginger rhizome powder and 50 g of neem kernel powder with 1 kg of any of the pulse varieties such as cowpea, soybean, red gram, etc (24).
- The following practice is a traditional measure followed by several farmers for storage pest control. Spread the leaves of neem and pungam layer bylayer over a cloth placed in a vessel for 1/4 feet. Then fill the vessel with seeds up to the surface level and cover it with a thick layer of sand to prevent pest attack.
- Seed coat of Mahua *(Madhuca latifolia)* @1-1.5 kg per kg of paddy seed is mixed before storage (25).

ii. Other plant products in pest control

- Mix 50 g of custard apple seed powder with 1 kg of any of the pulse varieties like soybean, cowpea, red gram, etc., to prevent the attack of the pulse beetle (26).
- Mix the seeds of Maize, Wheat, etc., with dried fruits and leaves of *Vantulsi* (wild Tulsi-*Ocimum*) at a ratio of 1:100 to prevent the weevils in storage (27).
- Store cereals and millets in bags or baskets made from the date palm fronds and after mixing it with neem leaves and ash. Plaster the top portion with cow dung to prevent the entry and spread of insects (28, 29).
- Mix green gram seeds with mustard oil@ 10-15 mL per kg of seeds and store it in earthen pots covered with a dry cloth (30).

iii.Wood ash in storage pest control

Wood ash is a safe and effective pest control material. Mix equal quantities of seed and wood ash to prevent the attack of beetles and other storage pests. *Lantana camara* leaf ash is very effective against pests attacking the sprouts of stored potato (31, 32).

Seed storage is an important process in maintaining the viability and vigour of the seeds during storage period. Different storage structures are available based on the duration of the seed storage. Storage structures can be classified into indigenous structures and modern structures.

7. Indigenous methods / structures

i. ***Gourd casing:*** The traditional method of seed storage is the use of the outer casing of gourd vegetables. These are used to store the seeds of vegetable crops. In some cases, gourd-shaped vessels made of clay or gourd-shaped baskets are also used for storage. If it is a basket, then it should be tightly plastered with mud (33).

ii. ***Kuthir:*** Farmers store the cereals in tall mud pots or bins, which is known as kuthir in Tamil. These are made up of clay soil and plant fibers. Sometimes husks of cereal crops can also be mixed with clay to make the storage structure stronger (34). The mud pot of about 1 -3 m in height has a narrow opening at the top and is covered with a tight lid. Seeds and grains can be stored in it and can be taken out only through the top opening (33, 35, 36).

iii. ***Kodambae:*** These structures are built close to the houses of the farmers. Big stones are placed concentrically at the base of the floor. Wooden sticks are placed over the stones to form a platform over the stones. The structure is round. Side walls of about 1 m in height are built using mud (red soil) or cement and bricks (37). On the top of the cylindrical structure, a conical shaped roof is built using bamboo sticks or coconut fronds. In the roof, an opening is made with a wooden board for a person to enter and collect the seeds as and when needed. Farmers use ladders to climb over the roof and to collect the seeds (38). The conical tip of the roof is covered with an inverted pot to avoid the seepage of rainwater inside the storage structure. The capacity of such kodambae is 1000 kg (39, 40).

iv. ***Thombarai:*** This type of storage structure is built using *Acacia* (thorn tree) wood and is rectangular. It is built at a height of 1 m from the ground level with four supporting wooden pillars at the bottom (41-43). The top of the structure has a small door with an opening for collecting and pouring the seeds. After filling the grains, the straw is spread over the top and sealed with mud. This structure is useful for preventing the seeds from storage pests and from rodents. The capacity of such a storage container is 1000 kg (44).

v. ***Earthen pots:*** Earthen pots made of clay to a convenient size are used from the olden days for storage purposes. The walls of the pot are coated with clay and the mouth of the pot is closed with stiff cow dung paste reinforced with cloth. Pots are arranged vertically one over the other depending upon the size of the pot. The capacity of the pot varies according to the size of the pots (45).

vi. ***Marathombai:*** This type of wooden structure is used to protect the seeds/grains from insects, moisture, mold growth and from the attack of birds and rodents (46). The wall of rectangular thombai is made using wooden boards to a height of 1.5 - 2 m and is built 80 cm above the ground level and supported with four wooden poles. The whole unit is split into 4 equal parts and each unit is used as a drawer for storage purposes (47, 48). The tight wooden board is placed at the top as a roofing material. A small outlet provided at the base is used for the removal of seeds from the storage structure. The capacity of such a storage container is 1000 kg (49).

vii. ***Kalangiyam:*** Rectangular brick walls are constructed with a strong concrete base inside the farmer's house. The walls are smoothly plastered to avoid the entry of insects and their larvae (50). The wooden lid at the top is used for the loading and unloading of the storage materials. Dimensions and capacity of the structure may vary depending on the farmers' requirement (51, 52).

viii. ***Puri***: It is constructed with the help of paddy straw over a hard surface of the ground after a layer of loose straw is provided at the bottom. This is done to prevent the absorbance of moisture from the ground. After loading the seeds, the structure must be covered with straw in such a way as to form a conical roof (53). It is easily prone to damage by rodents; hence the side wall can be built with the help of brick/cement concrete. The capacity of such storage containers is 3 - 20 metric tonnes (54).

ix.Gunny bags

Gunny bags are used for storing seeds which are durable and inexpensive. They are easy to handle and it allows the circulation of air to keep the seeds cool. They can be stacked in the household area itself. No special storage area is required for storing in gunny bags (55). Well before storage, gunny bags should be treated with 10 % neem kernel solution. Soak the gunny bags in neem kernel extract for 15 min and shade dry before use. New gunny bags should be soaked for 30 min. Dried bags are used for storing the seeds. Seeds can be protected from pest attacks for upto 4 months (56). After 4 months, seeds are to be dried and the bags are to be treated with neem kernel extract again. Capacity of the bag varies from 10 - 75kg.

Conclusion

Indigenous Traditional Knowledge (ITK) plays a crucial role in supporting sustainable agriculture and enhancing food security, especially in rural and underprivileged communities. The various practices discussed in this paper illustrate the depth and effectiveness of ITK in different aspects of agricultural management. Traditional methods, such as rainfall prediction using astrology and Panchanga, demonstrate a deep understanding of local climatic patterns. Sustainable practices, including the use of botanicals and biopesticides, reduce reliance on synthetic chemicals, promoting environmental health. Indigenous seed storage techniques and natural pest control methods ensure the preservation of seed quality and grain protection. In summary, ITK provides invaluable insights that are essential for sustainable agricultural practices. To fully integrate Indigenous Traditional Knowledge (ITK) into modern practices, future research should focus on documenting and validating ITK through scientific collaboration while respecting Indigenous rights and intellectual property. Policies should support the inclusion of ITK in environmental management, agriculture and healthcare, ensuring Indigenous communities lead decision-making processes. Technological advancements, such as digital platforms and AI-driven databases, can help preserve and share ITK while safeguarding cultural sensitivity. Strengthening partnerships between Indigenous knowledge holders and researchers will be key to ensuring ITK remains a vital and evolving resource for sustainable development.

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Authors' contributions

TKT wrote the manuscript draft and TVR and RC contributed to the discussion. All the authors have read and approved the manuscript.

Compliance with ethical standards

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