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Utilizing the Multi-Faceted Potential of *Shorea robusta* in 2023: A Comprehensive Review

Pramod Yadav, Dr. R. S. Antil
Amity Food and Agriculture Foundation, Amity University Uttar Pradesh, India

Abstract: ***The Sal tree (Shorea robusta), which is found in South and Southeast Asian tropical forest, has attracted increasing interest in its potential utility for a variety of purposes, including as a source of timber, fuel, and medicinal compounds in recent years. This comprehensive review examines the geographic distribution of Sal trees, emphasizing their presence in diverse ecosystems beyond India. The paper begins by describing the taxonomy and distribution of the Sal tree and then summarizes the current state of knowledge regarding its ecological role in tropical forests. Furthermore, the paper reviews the various uses, including a source of timber, fuel, and medicinal compounds. Finally, the paper discusses future research directions and potential areas for further study. Research and development initiatives explore the potential of SSC, bridging the gap between traditional knowledge and modern agricultural practices. Despite receiving relatively less research attention compared to others, ongoing research projects are shedding light on Sal trees' various properties and applications. Collaboration, improved communication, and innovation offer opportunities to further unlock the Sal tree's potential in the future.***
Keywords: Sal Seed Cake (SSC); Timber; Fuel; Medicinal compounds; Tropical forests.

I. INTRODUCTION

The Sal tree (*Shorea robusta*) is a native tree of India, and it is mainly known for hard and durable wood. Sal tree has multiple uses, both for its wood and for its other products [1]. Sal wood, which is resistant to pests and decay, is widely used in construction to make assorted items, such as doors, windows, furniture, flooring, poles, beams, and other structural components. Sal wood is also used to make various household products, such as utensils, bowls, and other items [1], [2]. Sal trees are also an important food source for several animal species, such as elephants, deer, and birds. The leaves, seeds, and fruits of Sal trees are edible and are a significant part of the diet of these animals. Moreover, Sal trees have various medicinal properties such as the traditional use of bark to treat ailments like diarrhea, fever, and skin conditions. The leaves are used as diuretics and to treat sore throats and coughs [2], [3]. Therefore, this systematic review paper aims to update the utility potentials of Sal trees in 2023. It involves a comprehensive examination of the latest research and developments conducted on Sal trees, including their potential uses in areas such as forestry, medicine, and agriculture. It also aims to identify gaps in current knowledge and areas where further research is needed to fully understand and utilize the potential of Sal trees. The ultimate goal is to provide a valuable resource for scientists, policymakers, and practitioners working in these fields and to contribute to the sustainable management and conservation of this species.

II.GEOGRAPHY AND CHARACTERISTICS OF SAL TREES

A. Geographical Presence of Sal tree forest

Shorea robusta is a widely distributed in the Indian subcontinent and other tropical and subtropical regions of the world. However, the distribution of Sal trees depends on several factors, such as geographical location, climate, and soil conditions, and it may change over time [1]. In India, Sal trees are prevalent in the Western Ghats, where they occur in various habitats, such as moist, humid forests, riverbanks, valleys, and low-lying areas. They cover an area of approximately 1.16×10^5 km^2 [4]. Sal trees can be seen in other parts of the world as well, such as Africa and Latin America. Sal forest is a type of tropical moist deciduous forest that occupies over 1.1×10^6 ha in the region and is traditionally managed for timber production [5].

B. Physical Appearance and Properties

Shorea robusta is a tall, deciduous tree species that has a straight, cylindrical trunk with a diameter of up to 1.2 m and a height of up to 36 m [6]. The bark is rough and fissured, and it has a gray or grayish brown color. The tree has a dense dark green canopy of oblong or elliptical leaves. The flowers are small and white or yellowish in color, and they have a sweet fragrant aroma. The flowers are arranged in clusters and are pollinated by insects, and flowering is influenced by several factors, such as temperature, humidity, and light intensity, and it occurs during the spring and summer months [6]. The flowers have various uses, such as food flavoring,

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perfumes, cosmetics, insect repellents, garlands, and decorations. After flowering, the Sal tree produces small, hard, woody capsules that contain seeds. The capsules are green when young but turn brown or black when mature. They are oblong or elliptical in shape and approximately 2.5 cm in length, and unripe fruits that are approximately 1-2 cm in diameter are typically small, round, and green but turn yellow or orange when ripe. They have tough, leathery outer skin and juicy, sweet, or sour flesh inside and typically contain a single seed. The seeds are oval in shape, with a smooth, glossy exterior and a pale yellow to brown color. They have an average length of approximately 3-4 cm and a width of approximately 2-3 cm [2]. The seeds are rich in nutrients and have a balanced ratio of macro- and microelements. They contain elevated levels of protein, as well as significant amounts of carbohydrates, dietary fiber, and various minerals, such as calcium, phosphorus, and iron, and these nutrients are essential for the good health of both animals and humans.

III.EFFECTS ON SOCIOECOLOGICAL AND ENVIRONMENTAL TRANSFORMATIONS

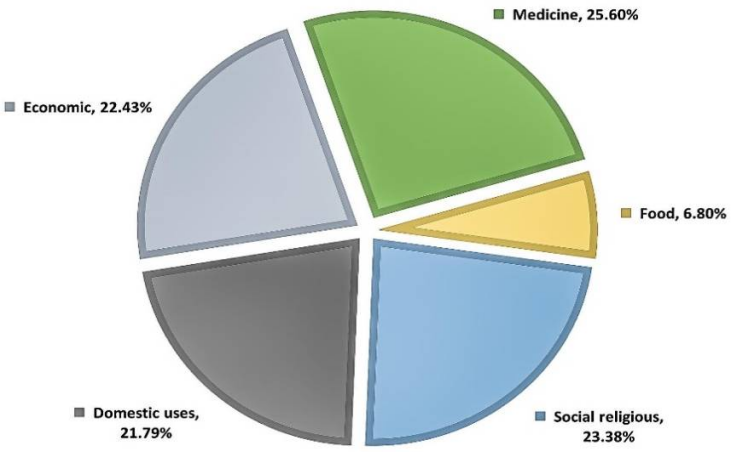


Figure 1. Sal tree use aspects reported by Khatun, 2020 [7].

Shorea robusta is a tall, evergreen tree species that forms dense forests in the Nepalese terai and other parts of South Asia. According to a 2020 study on 120 households (60 from each village) by a multistage random sampling method through a structured questionnaire and analysis using descriptive statistics and the chi-square test, it is a vital component of the forest ecosystem and the livelihood of tribal people [5], [7]. Tribal communities use Sal trees for fifty-one different purposes, such as income, food, fuel, fodder, construction, furniture, thatching, ropes, edible fruits, oil from seeds, and medicine [2]. It is used for tanning leather from tannins, which are natural substances that help to preserve leather. Sal trees are also considered sacred and revered for their spiritual significance by some tribal communities.

They are associated with various rituals and ceremonies, such as the Sarhul festival [8]. A study in 2013 reported that Sal tree has a high use value (UV) of 86%, indicating its importance for the livelihood of tribal people. The highest UV was recorded for resin (37%), followed by leaves (23%) and bark (15%). Sal trees also provide ecosystem services, such as soil erosion prevention, shade and shelter provision, water regulation, oxygen production, and food provision [5]. Sal forests also play a key role in conservation of landscape-level because they cover a substantial proportion outside to protected areas in the Nepalese terai which are consider as corridors for wildlife in the Terai Arc Landscape program [9]. Sal forests also provide essential habitat and resources for diverse fauna, including avian, mammalian, reptilian, and amphibian species. The canopy of Sal trees offers shelter and protection for arboreal and volant animals, such as birds, monkeys, and bats. The flowers of Sal trees are a major source of nectar for various pollinators, such as bees, butterflies, and hummingbirds. Gautam and Devoe in 2006 suggested that silvicultural practices that account for wildlife needs are crucial for the sustainable management of Sal forests [1]. This implies that forest management practices should aim to preserve or enhance the habitat quality of Sal forests for wildlife. For instance, forest managers should avoid clear-cutting Sal forests, which can degrade important wildlife habitats. Instead, they should apply silvicultural practices that maintain a diverse composition of tree species and age classes, which will offer a more suitable habitat for a broader range of wildlife [1]. However, there are some challenges and threats to the conservation and management of Sal trees, such as overexploitation, deforestation, climate change, and lack of awareness. The government and policy makers should work to improve

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the livelihood of tribal people using Sal trees as an important forest resource and nontimber forest product (NTFP), such as participatory forest management, value addition, market linkages, and awareness campaigns (Khatun, 2020).

IV.SCIENTIFICALLY PROPOSED POTENTIAL USES OF SAL TREE

A. As Organic Manures and Insect Repellents

SSC, also known as oil cake or meal, is a byproduct of the oil production process. It is made by pressing the seeds of a plant to extract the oil, leaving behind a solid residue that is high in protein and other nutrients, which is often used in animal feeding, such as to supplement the diet of livestock, including poultry, swine, and ruminants. It is a reliable source of the amino acids' lysine and methionine and minerals, fiber, and vitamins, which are a necessity for a proper growth and development of animals and help to increase milk production in dairy cows [10]. Sal seed cake is also used as a fertilizer for crops that improve soil fertility and crop yields and is particularly effective in increasing the yields of nitrogen-fixing crops, such as beans and peas. A study in 2020 evaluated the effectiveness of Sal seed cake as an organic manure and nitrification inhibitor for rice cultivation against the effects of urea and farmyard manure on the soil properties, plant growth, yield, and nitrogen use efficiency of rice and reported that it improves in the soil nitrogen, phosphorus, organic carbon, and potassium and reduces the pH of soil and bulk density compared to urea and farmyard manure [11]. It enhances the plant height, tiller number, leaf area index, root length, chlorophyll content, root dry weight, root volume, and root-to-shoot ratio of rice compared to urea and farmyard manure. This study also reported that it increases the straw yield, grain yield, harvest index, biological yield, and nitrogen use efficiency of rice compared to urea and farmyard manure. According to Singh et al. 2016, the application of Sal seed cake at 5 tonnes per hectare increased the grain yield of wheat by 23.8% and rice by 19.6% compared to the control (no manure or fertilizer). In a similar pattern, Singh, 2011, reported that in value addition of Sal seed cake, the N:P:K ratio also increased by 17.8:40.9:19.2%, as mentioned in [11].

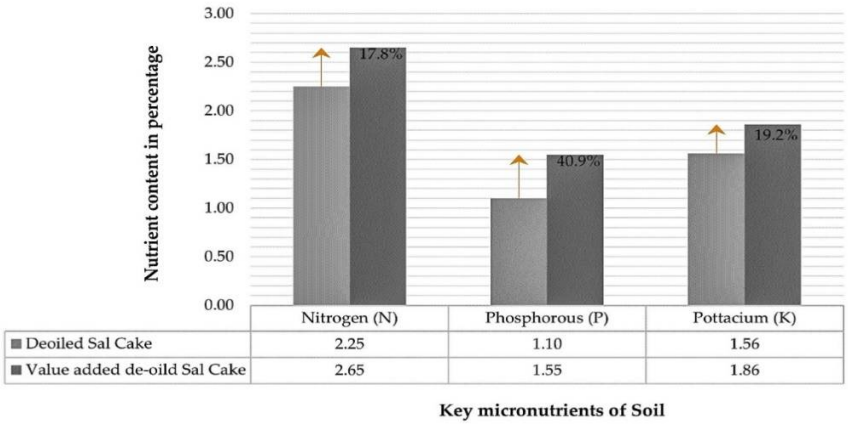


Figure 2. Deoiled Sal cake vs Value added deoiled Sal cake [11].

Another study in 2013 investigated the effectiveness of SSC as an inducer for production of protease enzyme from Aeromonas sp. S1 and its uses are kitchen wastewater treatment. They found that SSC could enhance protease production by 5.13-fold compared to the control [12]. They also found that protease could reduce the total suspended solids, biological oxygen demand (BOD), and oil and grease of kitchen wastewater by 74%, 37%, and 41%, respectively, after 96 h of treatment under static conditions [12]. They concluded that SSC could be used as a cheaper media supplement for protease production [12]. Another study that explored the mechanical, chemical, and physical, properties of Sal seeds, kernels, and oil found that the kernels had the highest oil content (30.20%, w/w) and protein content (14.35%, w/w) and reported that al oil had a high iodine value (94.5 g I2/100 g), indicating its unsaturated nature, and a high saponification value (197 mg KOH/g), indicating its potential for soap making. They reported that Sal oil higher content of oleic acid (46.23%) and linoleic acid (34.07%), which are essential fatty acids for human health [13]. The use of Sal seed cake as organic manure has a number of environmental benefits, such as being a biodegradable, sustainable and renewable resource because it is produced from a byproduct of the oil production process. One research team found that seed cake can be used as a natural pest repellent, as it contains compounds that are toxic to certain insects [14]. Sal seed cake can be used as a natural dye, as it contains pigments that can be extracted and used to color fabrics and other materials [14].

Table 1. Sal tree forest nutrient content (kg/Ha) [10].

Plant part	P	K	N	Mg	Ca	Total
Bark	8	58	85	35	257	443
Bole	27	75	242	51	125	520
Branches	8	35	101	20	115	279
Leaves	6	18	59	7	40	130
Twigs	3	14	34	4	35	90
Total	52	200	521	117	572	1462

B. As Medicine and Drugs

Various pharmacological properties, such as antibacterial, anti-inflammatory, analgesic, antioxidant, astringent, antiulcer, digestive, expectorant, hypolipidemic, hepatoprotective and wound healing properties, have been reported for Sal tree products/compounds [5]. Some of the major applications of Sal tree products/compounds are as follows:

1) Wounds and Pain

The resin and heartwood of Sal trees have been applied externally or internally for the treatment of wounds and ulcers. The resin exhibits astringent and antiseptic properties that stop bleeding and prevent infection. Heartwood displays anti-inflammatory and antioxidant properties that reduce inflammation and promote healing [15]. A paste or powder of resin or heartwood can be applied on the affected area or ingested with water or milk. A decoction or infusion of the flowers can also be used as a wash or gargle for wounds and ulcers in the oral cavity or pharynx [15]. A study was conducted on the ethanolic extract to assess the analgesic activity from *Shorea robusta* resin (SRE) in different pain models in animals on tail flick tests (central analgesia) and hot plate, acetic acid-induced writhing, formalin-induced hind paw licking, carrageenan-induced hyperalgesia, and postsurgical pain (peripheral analgesia). They found that SRE produced significant antinociceptive effects in all the pain models, as shown by increased reaction time, reduced writhing and licking, and increased pain threshold and paw withdrawal threshold. The authors concluded that SRE has marked analgesic activity in both central and peripheral mechanisms of pain. They suggested that the incidence of flavonoids, lignans, terpenoids, and phenols in SRE may be responsible for its analgesic action [16].

2) Skin Disorders

The resin and heartwood of Sal tree have been used for various skin disorders, such as leprosy, eczema, psoriasis, scabies, ringworm, acne, boils, and burns [15]. The resin possesses antibacterial and antifungal properties that kill pathogens and prevent secondary infection. Heartwood exhibits anti-inflammatory and antioxidant properties that soothe the skin and reduce itching and irritation [5]. A paste or powder of resin or heartwood can be applied on the affected area or ingested with water or milk. A decoction or infusion of the flowers can also be used as a wash or bath for skin disorders [5].

3) Digestive Disorders and Anti-obesity

The resin and heartwood of Sal trees have been used for various digestive disorders, such as indigestion, constipation, diarrhea, dysentery, peptic ulcers, colitis, and hemorrhoids. The resin has carminative and stomachic properties that stimulate digestion and relieve flatulence. Heartwood has antiulcer and anti-inflammatory properties that protect the gastric mucosa and reduce inflammation in the intestines. A paste or powder of resin or heartwood can be ingested with water or milk. A decoction or infusion of the flowers can also be used as a drink or enema for digestive disorders. A study conducted in 2012 investigated the antiobesity effect of Sal tree leaf extract on induced obesity by MSG (Monosodium glutamate) in albino rats by injecting it subcutaneously for 14 days. This study orally administered for 28 days of variables doses of the extract and measured various parameters, such as body weight, food intake, lipid profile, liver function, and antioxidant status. The results showed that the extract significantly reduced the body weight, low-density lipoprotein (LDL), serum cholesterol, food intake, triglycerides, and liver enzymes of the obese rats. The extract also increased the high-density lipoprotein (HDL) and antioxidant levels of obese rats [17].

4) Respiratory Disorders

The resin and heartwood of Sal trees have been used for various respiratory disorders, such as cough, cold, bronchitis, asthma, tuberculosis, and pleurisy. The resin has expectorant and antitussive properties that loosen and expel phlegm and relieve cough [18].

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Heartwood has anti-inflammatory and antioxidant properties that reduce inflammation and oxidative stress in the lungs. A paste or powder of resin or heartwood can be ingested with water or milk. A decoction or infusion of the flowers can also be used as a drink or inhalation for respiratory disorders [18], [19].

5) Reproductive Disorders

The resin and heartwood of Sal trees have been used for various reproductive disorders, such as leucorrhea, gonorrhea, menorrhagia, menopause symptoms, impotence, spermatorrhea, and seminal weakness [20], [21]. The resin has astringent and antiseptic properties that control abnormal discharge and prevent infection. Heartwood has hypolipidemic and hepatoprotective properties that lower cholesterol levels and improve liver function. A paste or powder of resin or heartwood can be ingested with water or milk. A decoction or infusion of the flowers can also be used as a drink or douche for reproductive disorders[21].

V.GOVERNMENT INTERVENTION

The livelihood and culture of many tribal communities in India face multiple socioeconomic challenges that threaten their well-being and survival. To address these issues, the Indian government and other global governing bodies have initiated several interventions to enhance the livelihood of the tribal people and conserve Sal tree forests [22]. These interventions include the establishment of protected areas, the implementation of policies and regulations, the promotion of research and development, and the support of value-added industries. Protected areas are designated regions where human activities are limited or regulated to preserve the natural resources and biodiversity of the area [23]. They are one of the main strategies for conserving Sal tree forests, as they prevent or reduce the threats of deforestation, degradation, and fragmentation. Some examples of protected areas for Sal tree forests are Chitwan National Park, Bardia National Park, and Shuklaphanta National Park [24]–[26]. These parks not only protect Sal tree forests but also provide habitat for many endangered wildlife species, such as one-horned rhinoceros, Asian elephant, Bengal tiger, and swamp deer. Policies and regulations are another important mechanism for conserving Sal tree forests, as they control or influence the use and management of these ecosystems. They may include laws that prohibit or restrict the logging of Sal trees or the conversion of Sal tree forests for other land uses, such as agriculture or urbanization [27]. They may also include incentives that encourage the sustainable use and management of these ecosystems, such as payments for ecosystem services, community forestry, or certification schemes. These policies and regulations aim to balance the conservation of Sal tree forests with the development needs of the tribal people [27]. Research and development are key components of enhancing the livelihood of the tribal people and conserving Sal tree forests, as they generate new knowledge and innovations that can improve the productivity and quality of these ecosystems. One of the major research programs launched by the Indian government is to assess the potential of SSC as organic manure. SSC is a byproduct of Sal seed oil extraction, which is widely used in traditional medicine, aromatherapy, and incense making. SSC has been found to have high nutrient content and beneficial effects on soil health and crop growth. As chemical fertilizers damage the soil every year of their use and the trend of organic farming is growing globally, SSC can be a viable alternative that can enhance the agricultural income of the tribal people [28]. Value-added industries are another crucial aspect of enhancing the livelihood of the tribal people and conserving Sal tree forests, as they create new markets and opportunities for these ecosystems.

As mentioned previously, Sal tree has various uses in traditional medicine, aromatherapy, and incense making. These industries have enormous potential to grow and create employment opportunities for the tribal people. Moreover, these industries can also increase the value and demand of Sal tree products, which can motivate tribal people to conserve these ecosystems [20]. Furthermore, these industries can also promote the cultural identity and heritage of the tribal people, as Sal tree is a symbol of their religion and spirituality. In conclusion, Sal tree forests are not only a source of livelihood for the tribal people but also a symbol of their culture, religion, and identity. By conserving and promoting these ecosystems, the Indian government and other global governing bodies are not only protecting the environment but also respecting the rights and dignity of the tribal people. The interventions discussed in this paper are some of the examples of how these objectives can be achieved through a comprehensive approach that integrates conservation and development [22], [23], [27].

VI.CURRENT RESEARCH TREND

The Sal tree (*Shorea robusta*) and its seeds are valuable assets for various purposes, but they have received less research attention than other tree species. This is attributed to numerous factors, such as limited funding, capacity, and demand for research on Sal trees. However, several ongoing research projects are focused on the Sal tree and its seeds, conducted by researchers and scientists from different countries and disciplines. These projects aim to understand the various properties and uses of Sal tree and its seeds,

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such as their medicinal, nutritional, sustainability, and environmental aspects. The medicinal properties of the Sal tree and its seeds are one of the research topics that explore their potential applications in traditional and modern medicine. This research involves studying the chemical composition of Sal tree and its seeds, as well as conducting clinical trials to assess the efficacy of Sal tree-based remedies. For instance, Singh et al. (2012) investigated the anti-inflammatory and analgesic activities of Sal seed oil in animal models and found that it had significant effects comparable to standard drugs [20]. The nutritional properties of Sal seeds are another research topic that examines their potential applications as a food source. This research involves analyzing the protein, carbohydrate, fiber, and mineral content of Sal seeds, as well as their digestibility and bioavailability. For example, Kumar et al. (2018) evaluated the nutritional quality of Sal seed flour and found that it had high protein (18.6%), carbohydrate (64.4%), and dietary fiber (12.8%) content, as well as various minerals such as calcium, iron, zinc, and magnesium [29]. The sustainability of Sal tree forests and the impact of different management practices on their health and productivity are also important research topics that assess the optimal use and conservation of these ecosystems. This research involves analyzing the growth rates and regeneration patterns of Sal trees, as well as studying the impacts of logging and other activities on Sal tree forests. For example, Chaturvedi et al. (2018) assessed the impact of selective logging on Sal tree forests in India and found that it reduced the basal area, volume, and biomass of Sal trees by 23%, 25%, and 26%, respectively [30]. The environmental impacts of Sal tree forests are another research topic that investigates their role in regulating water cycles, mitigating climate change, and supporting biodiversity. This research involves analyzing the carbon sequestration potential of Sal tree and studying the impacts of these ecosystems on local and regional climates. In addition to these ongoing research topics, there are also some opportunities that can facilitate more research on Sal trees in the future. One opportunity is to foster collaboration among researchers from different disciplines, institutions, countries, and regions who work on similar or complementary topics related to Sal tree. This can help to share resources, expertise, data, and ideas among researchers and enhance the quality and quantity of research outputs [31], [32]. Another opportunity is to improve communication among researchers, policymakers, practitioners, communities, and other stakeholders involved in or affected by the use and management of Sal trees. This can help to disseminate research findings, raise awareness about the importance and benefits of Sal trees, and solicit feedback and input from relevant stakeholders. A third opportunity is to foster innovation and creativity among researchers and scientists working on Sal tree. This can help to develop new methods, techniques, tools, and products that can improve the productivity and quality of Sal tree products and services.

VII.DISCUSSION AND CONCLUSION

This review paper has provided a comprehensive overview of the utility potentials of the Sal tree (*Shorea robusta*) in 2023, encompassing a range of areas such as forestry, medicine, agriculture, and environmental conservation. The discussion section will delve into key findings, emerging trends, and the implications of the research presented in the preceding sections. The geographic distribution of Sal trees is influenced by numerous factors including climate, soil conditions, and geographical location. In India, they are widespread in the Western Ghats, covering a significant land area. However, the distribution of Sal trees is not limited to India; they are also found in regions such as Africa and Latin America. Understanding the geographical presence of Sal trees is essential for conservation efforts and sustainable management practices. Sal trees play a multifaceted role in the socioecological and environmental landscape [1].

They are indispensable for tribal communities, serving various purposes from income generation to food and medicine. The high use value of Sal trees underscores their significance in the livelihoods of these communities. Additionally, Sal forests provide ecosystem services such as soil erosion prevention, shade, shelter, water regulation, oxygen production, and food for diverse fauna. Recognizing the vital role of Sal trees in landscape-level conservation is crucial for preserving biodiversity. It is also noteworthy that silvicultural practices must incorporate wildlife needs to ensure the sustainable management of Sal forests [22], [27]. The utilization of SSC as an organic manure and insect repellent offers environmentally friendly alternatives for agriculture. The nutrient-rich content of SSC enhances soil fertility and crop yields, contributing to sustainable farming practices. Moreover, the application of SSC in kitchen wastewater treatment displays its versatility in addressing environmental challenges. Its role as a natural pest repellent and dye further underscores its value. Sal tree and its products have also been recognized for their medicinal properties [20]. They are used in traditional and modern medicine to treat various health problems including wounds, skin disorders, digestive issues, respiratory problems, and reproductive disorders. These applications are supported by scientific research, which validates their effectiveness. Sal tree-based remedies offer an alternative and potentially more sustainable approach to healthcare. Government interventions are essential for the conservation of Sal tree forests and the improvement of the livelihoods of tribal communities. The establishment of protected areas and the implementation of policies and regulations are critical steps in safeguarding these ecosystems [27]. Research and development initiatives, such as exploring the potential of SSC as organic

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manure, bridge the gap between traditional knowledge and modern agricultural practices. Value-added industries can provide economic opportunities for tribal communities while promoting cultural preservation. While Sal tree and its products have received relatively less research attention compared to other tree species, ongoing research projects are shedding light on their various properties and applications. Medicinal, nutritional, sustainability, and environmental aspects are the focus of these projects. Researchers are investigating the chemical composition of Sal tree and its seeds, conducting clinical trials, and studying their impact on soil health, crop growth, and carbon sequestration. Collaboration, improved communication, and innovation are key opportunities for further research on Sal trees in the future [33].

In conclusion, the Sal tree holds immense potential for various sectors, including agriculture, healthcare, and environmental conservation. Its importance in the lives of tribal communities cannot be overstated, making its sustainable management and conservation paramount. Continued research and humongous collaborative attempts are critical to undo the full potential of this valuable tree species and ensure its long-term survival.

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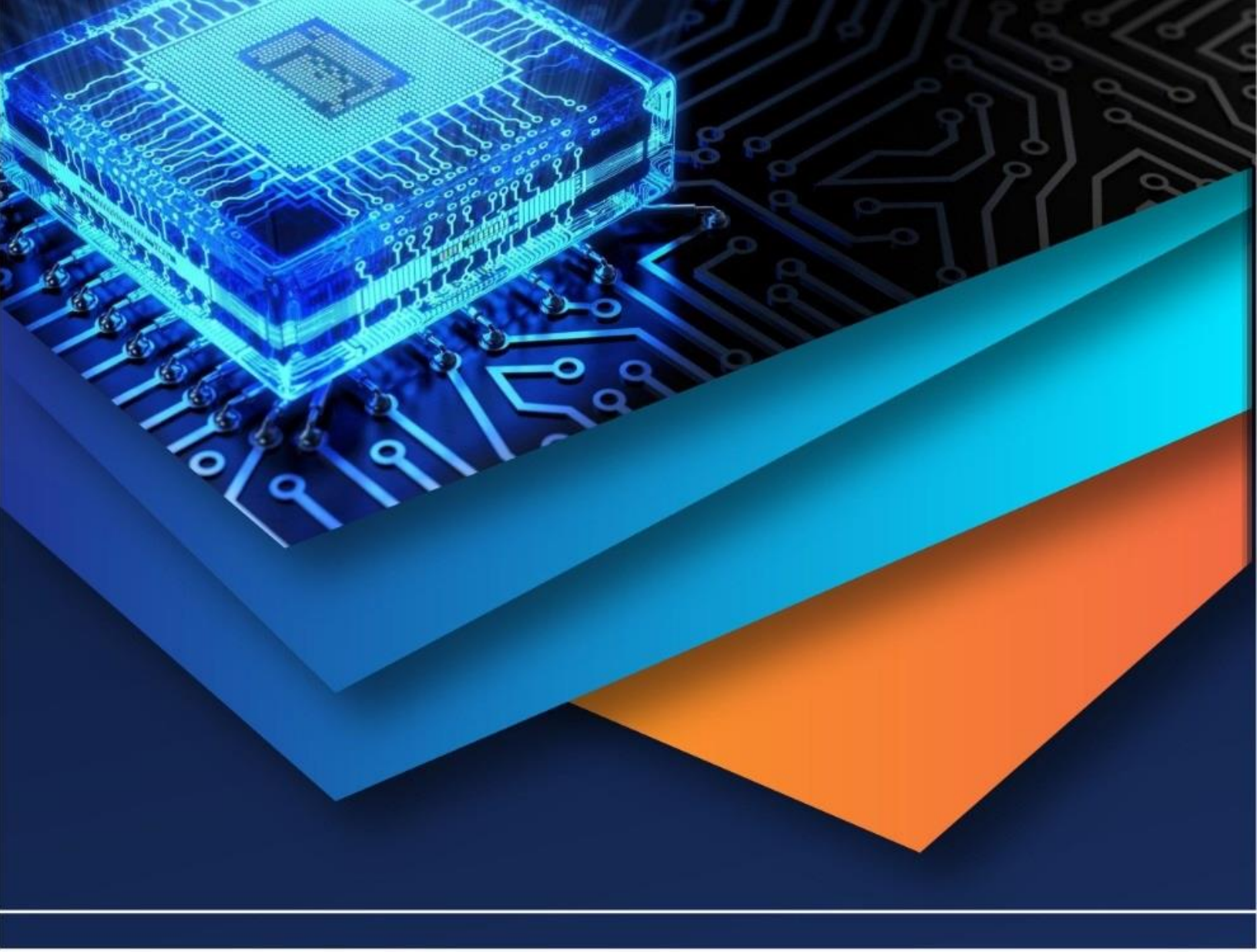
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