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Decarbonization through Regenerative Agriculture

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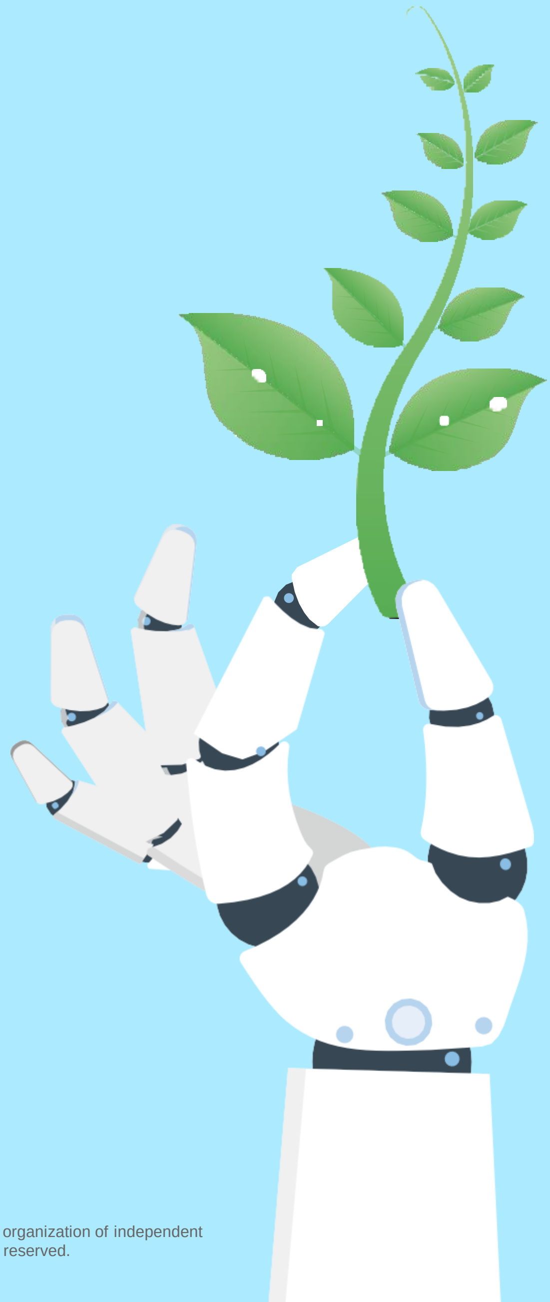
Regenerative Agriculture – Pakistan

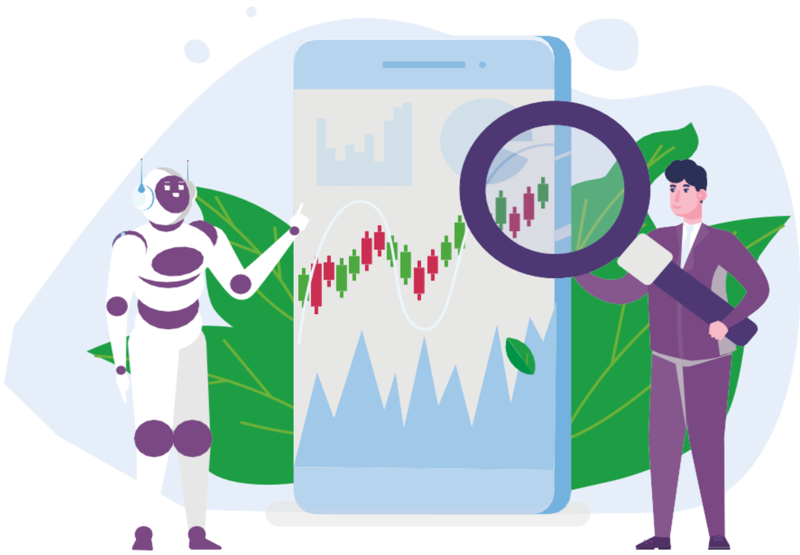
A Case for Change

With mainstream farming techniques, yields have increased significantly, providing our world's expanding population with affordable food. Agriculture still has a big impact on the environment, the climate, and other things. Regenerative and productive agriculture scaling can lower and even reverse these costs. Additionally, increasing productivity, restoring ecosystem function and natural capital, reducing reliance on inputs, and even broadening the farm's revenue streams to include carbon and ecosystem service payments might increase farm resilience and profitability. Better land management techniques and technologies can significantly increase agricultural productivity.

These can lessen the number of resources used, the inputs used in agriculture, and their environmental effects. In addition, higher productivity may theoretically free up more land for conservation. While the use of remotely collected data to inform land management and inputs, on-farm autonomous equipment and variable-rate technology, new genomics insights and tools, and a variety of improvements in breeding, feeding, and pasture practices are among the emerging technologies, practices like no-till cropping and controlled traffic farming have already been widely adopted.

Many approaches try to go beyond avoiding negative consequences and instead create beneficial environmental outcomes for agriculture, such as improving soil health and enhancing biodiversity on farms. To achieve these goals, farmers are implementing a variety of practices that mimic natural systems, such as replacing synthetic chemicals and fertilizers with organic alternatives, avoiding/minimizing tillage, eliminating bare soil, e.g., through cover crops, fostering plant diversity, encouraging water percolation into the soil, and integrating livestock and cropping.
The technologies, practices, and approaches along this spectrum are labelled in a variety of ways, including 'sustainable intensification' (focused on producing more on less land and with fewer inputs), 'organic' (focused on avoiding synthetic inputs), and 'regenerative' (focused on improving ecological function). The boundaries are blurred, and many land managers use a combination of methods.





Literature Review

The negative impacts of climate change can be witnessed in a drastic shift in weather patterns or rising CO2 levels (Malhi et al., 2021).

The rise of modern farming techniques, such as regenerative agriculture. Regenerative agriculture is an approach to farming that uses soil conservation as an entry point to regenerate and contribute to multiple ecosystem services. These were variously based on processes, e.g. the use of cover crops, the integration of livestock, and reducing or eliminating tillage; outcomes of the above practices are to improve soil health, to sequester carbon, and to increase biodiversity. (Schreefe & R.P.O. Schulte, 2020).

Regenerative agriculture improves soil organic matter content, resilience to drought, and better water infiltration to deliver wide-ranging benefits including the restoration of soil health, water quality, and biodiversity. (Ken E Giller & Hijbeek, 2021) ,(Sahu & Das, 2020; Gordon & Davila, 2022), (LaCanne & Lundgren, 2018),) (Chaudhry, Malik, & Sidhu,2004), (Lankford1 & On, 2022).

Regenerative farming can considerably contribute to the reversal of climate change by decreasing the agriculture sector’s carbon footprints, resulting in declining global warming (Qiang Jin et al., 2022). The concentration of carbon dioxide has been risen by 20%. (Malhi et al., 2021). Regenerative farming can considerably contribute to the reversal of climate change by decreasing the agriculture sector's carbon footprints, resulting in declining global warming (Brown, 2018).

Regenerative agriculture builds upon decades of research and experience from various fields like organic farming, agroecology, holistic land management, and agroforestry. This combination of indigenous knowledge and modern science creates a holistic approach to sustainable food production. (Burns,2021).

Carbon, up to 15 tons of it per acre per year, according to the United States Department of Agriculture, can stay locked in the earth as long as regenerative practices are maintained. From 1990 to 2019, agricultural emissions from all three critical GHGs_CO2, CH4, and N2O_increased 16% (Kamila Kazimierczuk et al., 2022).

It can be reasonably ascertained, based on extensive literature and academic and professional research, that regenerative, sustainable agricultural practices play a significant role in achieving the objective of CO2 emission reduction. Similarly, the agricultural sector is hugely dependent on variabilities in temperature, rainfall, and floods. It affects agricultural production, the food supply, commodity prices, and other aspects that eventually impact economic performance.

In terms of overall emissions as well as the distribution of contributions across farm gates, land use change, and pre- and postprocessing components. China had the most emissions (1.9 GtCO2 eq. yr1), followed by India, Brazil, Indonesia, and the USA (1.2–1.3 GtCO2 eq. yr1). The Democratic Republic of the Congo (DRC) and the Russian Federation followed with 0.5–0.6 GtCO2 eq. yr1, followed by Pakistan, Canada, and Mexico with 0.2–0.3 GtCO2eq yr1). (Tubiello, F. N et al., 2022).

Pakistan's Context

Agriculture is the source of approximately 70% of Pakistan's exports, directly or indirectly. Approximately 47% of the national territory is agricultural land, which is higher than the global average of 38% and spans an area of 30.5 million hectares. Approximately 65% of Pakistan's population resides in rural areas and directly or indirectly relies on agriculture for their livelihood. Currently, smallholder farmers in Pakistan are classified as 90% of the total number of farmers, which is 7.4 million. These farmers own less than 12.5 acres of land (5 hectares) and sustain thousands of regional communities. Pakistan's agriculture is primarily export-oriented, with over two-thirds of Pakistani produce being exported. Agriculture is a critical component of Pakistan's economy, contributing to 23% of the country's GDP and 70–80% of its export revenues. In 2023–2024, agricultural exports were valued at USD 5.2 billion.

Agriculture is dominated by livestock, which accounts for 62% of the total. Important crops (4.1%), other crops (3.3%), forestry (0.5%), and fisheries (0.3%) follow in that order. Pakistan has a total water availability of 72.7 MAF and two main cropping seasons: Kharif and Rabi. Over 82% of the agricultural land is irrigated, while 18% is rainfed. Winter-season cereals, including wheat, barley, gramme, lentils, rapeseed, and canola mustard, are cultivated in approximately 60% of the rainfed areas. Wheat and rice are the primary staple commodities, comprising 37% and 11% of the total crop area, respectively. Sugarcane and cotton are the primary economic commodities, contributing 0.9 and 0.3 per cent of the GDP, respectively.

It is a significant global participant in certain agricultural commodity markets, such as wheat, milk producers, cattle, and sheep. An increasing cohort of farmers are concentrated on "regenerative" approaches, and certified organic agriculture represents a very small but growing share of agricultural land. Pakistan's productivity has historically been superior but is exceedingly susceptible to climate-related hazards.

Pakistan's agricultural research and development sector possesses a robust technology and innovation capability, and Pakistan's producers have historically demonstrated an interest in achieving high levels of productivity growth.

Nevertheless, the agricultural sector is already experiencing substantial climate-related effects. It is predicted that productivity will decrease by up to 50%, and it is highly susceptible to future impacts, such as more frequent and severe fires, heatwaves, droughts, flooding, shifting water availability, frost risk, and biosecurity.

Furthermore, productivity enhancements may not necessarily enhance producers' profitability. Pakistan's agriculture has exhibited the capacity to implement enhanced land management practices swiftly.

A variety of enhanced land management practices, including precision agriculture, controlled traffic farming, and no-till cultivation, have already been implemented by most Pakistani farmers. A small but growing group of "regenerative" farmers are pioneering, experimenting, refining, and sharing various regenerative agricultural practices adapted to the Pakistani landscape. However, the evidence base for some of these practices is still limited, particularly regarding yields, costs, and profitability.

Additional enhancements are required to mitigate the sector's environmental consequences, which encompass:

- 34% of Pakistan's greenhouse gas emissions are attributed to livestock emissions, deforestation, and fertilizer application, with substantial additional emissions associated with agriculture and food included in other sectors, such as fertilizer manufacturing.
- Per capita water consumption in Pakistan varies by region, with rates ranging from 30 to 350 liters per person per day. Pakistan has the fourth-highest water consumption rate globally, with 97% of that water utilized for agriculture and irrigation. Nevertheless, Pakistan generates an annual water pollution of 10 trillion gallons due to its inadequate water reservoirs and significantly lower per capita water storage than other nations. Approximately 7.2 to 12 billion liters of freshwater are consumed annually, nearly three-quarters of the total.
- The purity of drinking water is inadequately monitored and managed. Pakistan is ranked 80th out of 122 nations in terms of the purity of its potable water. Coliforms, toxic metals, and pesticides are present in drinking water sources, including surface and groundwater, nationwide. Impacts on marine environments and the contribution to poor water quality as a consequence of chemical and sediment runoff, emphasizing industry initiatives to mitigate these effects.
- Land clearance for agriculture is currently underway in certain regions.
- An estimated 40-60% total soil loss, including up to 50% acidification of cropping and intensive grazing lands and a decline in soil health. The long-term consequences of COVID-19 are unpredictable.
- While there is no immediate or direct impact on domestic food security, Pakistan may experience unpredictable consequences as a result of increased global food insecurity. For instance, the World Food Programme anticipates acute food insecurity for up to 265 million individuals worldwide.
- Export markets may be disrupted, potentially leading to a decrease in demand for certain products, such as wine, seafood, and red meat, and an increase in border restrictions.
- Farming enterprises may encounter disruptions to long-term global supply chains for fuels, agrochemicals, and equipment, restrictions on the seasonal migrant workforce for harvesting, or shutdowns of processing and manufacturing operations as a result of outbreaks.

Key Takeaways – Potential for regenerative agriculture to contribute to a set of primarily environmental outcomes and productivity outcomes that impact environmental footprints.

Mitigation of climate change

Research has demonstrated that in certain situations, farms that have implemented regenerative practices can achieve carbon sequestration and emissions reductions. Nevertheless, this is extremely context- and practice-specific. In order to provide Pakistan with climate change mitigation solutions, it is necessary to conduct more detailed research on the potential of regenerative agriculture in various environments and land use contexts.

The health of soils and waterways

The potential to improve the health of soil and waterways in Pakistan is present through the implementation of regenerative agriculture practices. These practices have the potential to improve soil health and water management, which includes reduced water usage and improved water quality. However, the efficacy of these practices may differ depending on the specific practices that are used. In order to resolve specific matters, further research is required.

Biodiversity

There is evidence that regenerative agriculture can have a beneficial effect on biodiversity in Pakistan. These practices are beneficial for biodiversity conservation; however, they are insufficient to reverse the current decline. A more comprehensive approach is required, which integrates regenerative agriculture with broader strategies to safeguard and restore habitats in both agricultural and natural landscapes of Pakistan.

Land use and productivity

In comparison to conventional agricultural methods, the productivity of regenerative agriculture in Pakistan varies. In certain cases, regenerative practices may lead to lower yields, while in others, they may surpass conventional methods. The limited evidence regarding the land area required for regenerative versus conventional practices to produce the same quantity of food and fiber is a significant obstacle to evaluating comparative productivity. Furthermore, it is imperative to evaluate the demands for agricultural production and land in Pakistan in the context of the broader system-wide adjustments that are required for sustainable land use.

Profitability and resilience

In Pakistan, certain regenerative agriculture practices necessitate fewer inputs, which can result in cost reductions that can help offset the higher labor expenses that are frequently associated with these practices. Furthermore, regenerative farms have the potential to increase their profitability by taking advantage of price premiums. The evidence on the relative profitability of regenerative agriculture in Pakistan is inconclusive, necessitating additional research to directly evaluate the financial impact of sustainable agricultural practices that produce positive environmental outcomes.

Decarbonization

The Global importance of greenhouse gas (GHG) emissions has increased the focus on reducing emissions through climate-smart agriculture practices.

Globally, agriculture produces 20% of CO_2, methane produces 70% and nitrogen oxide produces about 90%.(Rehman & Ozturk, 2019)

While regenerative agriculture practices show potential for mitigating CO_2 and non-CO_2 (N_2O and CH_4) emissions (Kamila Kazimierczuk et al., 2022).

Decarbonization

Cover Cropping

Cover crops are crops planted primarily to control soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity, and wildlife in an agroecosystem. These crops are not done on purpose for harvest but are used to cover the soil. They play a crucial role in sustainable agriculture by enhancing soil health, improving nutrient cycling, reducing the need for chemical fertilizers, and preventing soil erosion. (Valentina Quintarelli et al., 2023). According to the USDA, cover crops include grasses, legumes, and forbs like annual ryegrass, oilseed radish, winter cereal rye, and oats, which can improve soil structure, increase moisture and nutrient content, and suppress weeds (USDA).
Cover crops sequester carbon by enhancing soil organic matter and reducing CO2 emissions from soil disturbance , cover cropping has the potential to sequester significant amounts of CO2e annually (Gordon & Davila, 2022) (Schreefe & R.P.O. Schulte, 2020).

Reduced Tillage/No-Till Farming

A growing body of research supports the potential of regenerative agriculture for decarbonization. A 2017 meta-analysis of 76 studies found that no-till farming increased soil organic carbon by an average of 0.4% annually. A 2020 study in Nature Climate Change estimated that widespread adoption of regenerative agriculture could sequester up to 1.2 billion tons of CO2e per year in the United States alone.
https://www.worldbank.org/en/topic/climate-smart-agriculture (Kenne & Kloot, 2019).
Regenerative agriculture promotes a No-Tillage policy that limits mechanical, chemical, and physical disturbance of soil; tillage destroys soil structure (Qiang Jin et al., 2022). It is constantly tearing apart the “house” that nature builds to protect the living organisms in the soil, which creates natural soil fertility and can reverse global warming by restoring the organic carbon content in the soil (Brown, 2018).

Nitrogen Fixing Legumes

Nitrogen is an important nutrient for plant growth, Traditionally, farmers rely on synthetic nitrogen fertilizers, but nitrogen-fixing legumes offer a more sustainable and cost-effective approach. These are plants, like soybeans, peanuts, clover, and alfalfa, that possess the incredible ability to convert atmospheric nitrogen (N2) into a usable form of ammonium. Ammonia is extensively used in agriculture, primarily as a nitrogen fertilizer, which is essential for plant growth. Nitrogen-fixing legumes, such as soybeans, peanuts, clover, and alfalfa, form a symbiotic relationship with bacteria called rhizobia, which reside in the root nodules of these plants. The rhizobia bacteria convert atmospheric nitrogen (N_2) into ammonia (NH_3) through a process called biological nitrogen fixation. The ammonia produced by rhizobia is initially released into the plant cells as ammonium (NH_4), which plants can directly absorb and utilize. This ammonium can then be converted into amino acids, proteins, and other nitrogenous compounds necessary for plant growth and development. (Toensmeier, 2016).

Rotational Grazing

Different grazing animals have diverse grazing patterns and manure compositions, enriching the soil with a wider range of nutrients and organic matter. Think goats nibbling on woody shrubs, chickens pecking at insects, ducks gobbling up slugs, and sheep grazing down weeds, all reducing dependency on chemical interventions such as insecticides and pesticides. (Sahu & Das, 2020). It improves grassland health, increases soil carbon sequestration, and reduces methane emissions from more efficient animal digestion.

Composting and Organic Amendments

Adding organic material to soil to improve soil health and microbial activity. Increases soil organic carbon and reduces methane emissions from organic waste decomposition. The net reduction in CO2 emission means increased soil carbon storage, which is commonly known as carbon sequestration (Md et al. et al., 2017).

Decarbonization

Summary of Mitigation, Implementation, and Time-Scale Potential for Selected Carbon Farming

Category	Practice and Impacts	Potential Global Mitigation Impact	Ease of Adoption by farmers	Readiness of Practice
Crop Management	Cover Crops	Medium	Easy	Ready
Tillage and residue management	Reduced tillage and crop residue management	High	Easy	Ready
Water Management	Rainwater harvesting and other strategies	Medium	Moderate	5-10 years
Rice paddy management	Straw retention, reduced flooding, nutrient management	Medium to High	Moderate to Easy	Ready
Biochar application	Application of biochar for fertility and carbon sequestration	High	Moderate	Still under development
Managed Grazing	Improved grazing management, fodder production, and diversification	Low	Moderate to Easy	Ready
Manure Management	Change feeds and Bio-digestion	High	Moderate to Easy	Ready
Livestock feeding	Methane-reducing feed and forage	Medium	Moderate	5 to 10 Years
Agroforestry	Integration of trees with crops	Medium	Moderate	Ready

What's needed?

Regenerative agriculture has the potential to provide a variety of benefits, including improved soil health and biodiversity. Albeit there is emerging evidence that regenerative practices can, in certain circumstances, reduce emissions and sequester carbon, additional research is required to gain a comprehensive understanding of their importance in the context of broader climate change mitigation and land use strategies.

Furthermore, there is an increasing body of evidence that regenerative agriculture can enhance adaptation and resilience to climate change by stabilizing productivity during weather fluctuations and enhancing the well-being of farmers in the presence of these obstacles especially in the water stress areas of Sindh and Baluchistan and similarly differently for the flood prone areas of Punjab and Sindh. These results are consistent with global research, which suggests that regenerative agriculture can have a beneficial effect on a variety of environmental outcomes. However, there are still voids in the evidence. We emphasis on the need to develop an outcomes-based framework to evaluate the effects at the National Level.

It is imperative to address the challenges in the food and land use sector by improving agricultural production, and practices that accomplish regenerative outcomes are instrumental in this endeavor. In order to facilitate the expansion of regenerative agricultural practices, we suggest the following interventions:

- Create a framework that is founded on outcomes and based on flora and fauna of Pakistan
- Invest in the research and create the body of evidence to facilitate decision making
- Encourage learning and experimentation on the farm and involve corporates to take hold of the farms
- The measurement and valuation of natural capital in agricultural systems should be integrated into the mainstream.
- Adopt a comprehensive approach regarding the entire system rather than in pockets or circuits or small areas
- Lessen the demand-side pressures on land by exploring opportunities for synergies with more intensive approaches, supported by technological innovation, to help address this to some extent.
- Ensure that land use is consistent with the national nature and climate objectives by coordinating action – A nation-wide, strategic approach to land use decision-making may support informed decisions about how to manage trade-offs, enabling a more equitable and just transition for farmers, consumers and other landholders.

We understand that these may become ESG initiatives for certain corporates and they can help government develop a better way to improve not only the regenerative agriculture agenda in Pakistan but overall, the decarbonization pathway for us.

Conclusion

Scientists have estimated that by implementing practices that promote increased carbon storage and reduce turnover rates of existing carbon stocks in agricultural soils, four to five billion tons of carbon can be sequestered annually in managed ecosystems (Kazimierczuk et al., 2023). Tillage can disrupt the long-term binding sites for humus, which is 50% carbon. In undisturbed soil, humus can persist for 100 to 5,000 years. (Rehman & Ozturk, 2019). A 2021 report funded by the Natural Resources Defense Council reported carbon sequestration of regenerative practices from various studies to range from 1.1-3.5% of total global annual emissions, assuming an emissions rate of 10 billion metric tons/year (Kazimierczuk et al., 2023).

For Pakistan, especially in the Punjab and Sindh region, promoting sustainable, regenerative agricultural practices, specifically in rural and developing regions with a documented reliance on agrarian economic production, can potentially affect levels of carbon and other harmful greenhouse gases, which are directly and indirectly responsible for rising temperatures around the globe. In countries like Pakistan, where economic development and growth have still not reached levels of technological and resource maturity as developed economies, the dependence on low-cost, non-renewable resources fuels much of a country's economic activities and growth; this, coupled with a lack of clear, consistent, and standardized policy-making and regulation around Climate Change and Environmental Protection can have significant impacts on how such countries continue to industrialize, develop, and contribute to the global carbon stock.

Not only would promoting regenerative agricultural practices promote cost-saving, inclusive solutions, but it would also have a cumulative impact on reducing rising global temperatures and helping the world achieve the limits set and agreed upon under the Paris Agreement.

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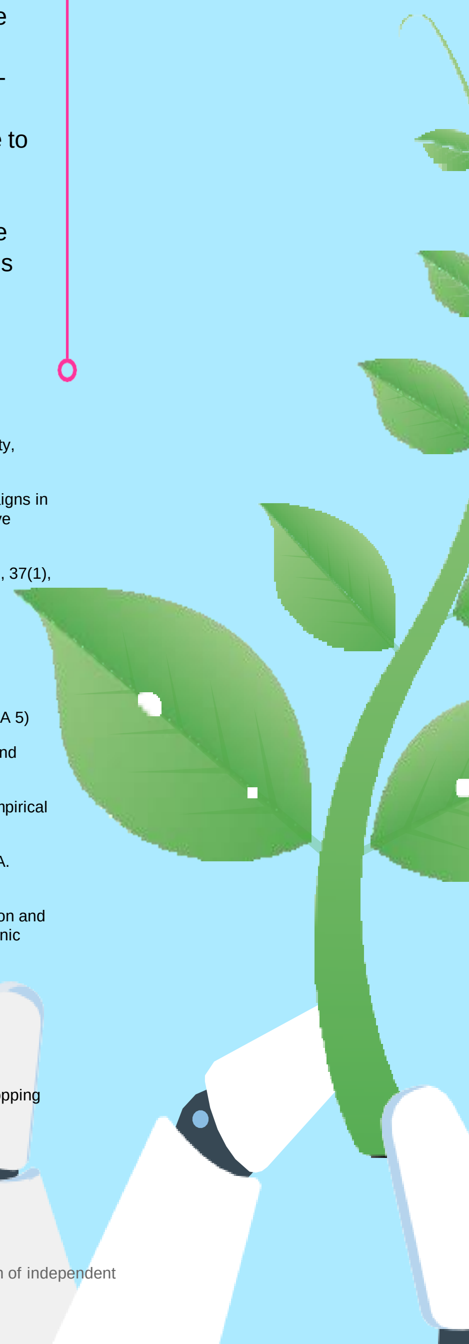

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