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Title:
Research on the Current Situation and Improvement of the Saline-Alkali Field ----the case of Huanghua, Hebei Province

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The Status of Saline-Alkali Land and Its Improved management Strategies
----the example of Huanghua, Hebei province

Abstract: As a kind of land resource with potential for development and utilization, saline-alkali land has received increasing attention under the background of gradually growing demand for arable land resources. This paper primarily studies the treatment and the achievements of saline-alkali soil in Huanghua region, especially the specific application of the N+2 (alfalfa+wheat\corn) grain-forage rotation model in the local area and its impact on local agricultural production, livelihood, and ecology. It aims to provide effective references for saline-alkali soil treatment in other regions of the world.

Keywords: saline-alkali land; N+2 grain-forage rotation model; agricultural achievement

I. Distribution and Characteristics of Salt-alkali Land

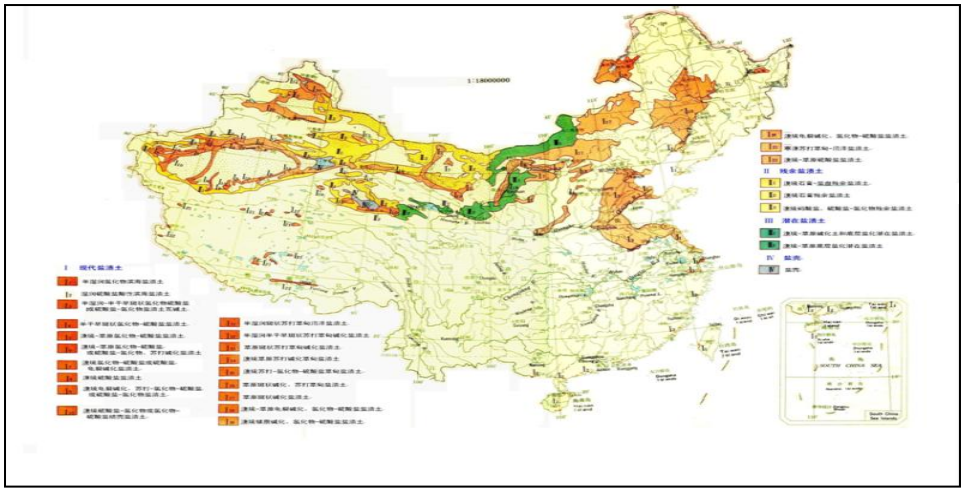
(I) Definition of Salt-alkali Land

Salt-alkali soil accumulates a significant amount of salt ions such as Ca2+, Mg2+, K+, Na+, Cl-, CO32-, HCO3-, etc. Its formation is attributed to both natural and human factors, often occurring in regions with arid climates, high groundwater levels, and low-lying areas without drainage outlets. As water evaporates, salts in the groundwater rise to the soil surface. During the process, these ions redistribute horizontally or vertically, leading to salt accumulation in the soil surface, soil hardening, destruction of soil structure, decreased soil porosity. Eventually, the normal growth of plants are affected by the poor air permeability and water permeability.Meanwhile,the growth, abundance, and metabolism of functional microorganisms in the soil are reduced, and the conversion rate of soil organic matter and soil fertility are decreased.

(II) Current Distribution of Salt-alkali Land

Soil salinization is a worldwide ecological issue, affecting nearly 932 million hectares of land. This issue leads to land degradation, decreased agricultural productivity, and even food security issues. Salt-alkali soil is concentrated in Africa, Asia, Oceania, and South America. Countries with large salt-alkali land are Australia, Kazakhstan, China, Iran, and Argentina, etc.

In China, salt-alkali land covers 17 provinces and regions, primarily in the northeast, north, and northwest, occupying approximately 36 million hectares, accounting for 5% of the nation's usable land area. The majority of this land is barren, with only about one-fifth being cultivated. Additionally, 17.5 million hectares of this land are under potential salinization threat, which has a significant impact on China's agricultural and animal husbandry development and ecological civilization construction. Improving salt-alkali land is a crucial measure to develop soil and increase per ca-pita land availability. Increasing investment in salt-alkali land improvement and strengthening collaboration between departments will contribute to ecological environment protection and sustainable economic development.



Picture 1 Current distribution map of saline alkali land in China

(III) Traditional Improvement Measures for Saline-Alkali Land

1. Physical Improvement Measures

The key to physical improvement lies in altering the physical and chemical properties of the soil, disrupting its capillary structure, and preventing the upward movement of salts to the surface. In practical applications, appropriate treatments are based on soil texture, structure, and permeability.

(1) Deep Tillage and Deep Ploughing

Deep loosening of the soil layer can enhance the infiltration speed and volume of rainwater, as well as the effect of leaching salts during summer rains and irrigation. This practice cuts soil capillaries off, reducing the amount of salt rising and thus lowering soil salinity. Without inverting the soil layer, residues, straw, and weeds remain mostly on the surface, which is conducive to moisture retention, wind erosion reduction as well as runoff delay, runoff intensity reduction, soil erosion mitigation, and water and soil conservation. Deep ploughing combined with organic fertilizer application, straw, and slag addition can not only increase crop yield but also improve soil physical and chemical properties, enhancing soil fertility.

(2) Surface Mulching

Surface mulching plays a crucial role in crop growth and soil health, which reduces evaporation , prevents soil salting, saves water, and increases crop yield. However, plastic films are difficult to degrade, posing potential secondary pollution to coastal ecosystems. Therefore, the benefits and side effects of plastic films in coastal saline-alkali land require further investigation, understanding, and evaluation.

2. Chemical Improvement Measures

Chemical measures not only improve soil structure, accelerate the process of salt and alkali removal, but also alter the composition and content of soluble salts in the soil and regulate the soil pH. Research shows that soil improvers primarily composed of gypsum or phosphor have significant effects on alkaline soil. Desulfurized gypsum is commonly used to improve heavily saline-alkali soil. The application of desulfurized gypsum prevents soil hardening, facilitates plant root growth and enhances the water and nutrient absorption capabilities of roots, ultimately achieving the purpose of improving saline-alkali soil. With irrigation measures and the principle of

"coming with water and flowing with water", these chemical measures can bring those displaced Na+ into the plow layer and achieve the goal of improvement of saline-alkali soil.

In conclusion, physical and chemical improvement measures are easy to promote. It can be generally applied under different land and soil conditions. However, in the long run, physical and chemical methods are not thoroughly effective in salt removal and require significant labor, limiting their promotion and application scope.

II. Research on Saline-alkali Land Treatment in Huanghua Port Area, Hebei Province

(I) Overview of Huanghua City

Located at the easternmost tip of the Heilongjiang Basin in the Haihe Plain, on the west coast of the Bohai Bay, and in the southeastern part of Hebei Province, Huanghua City covers a total area of 1,544.7 square kilometers, spanning between latitudes 38°09′ to 38°39′ north and longitudes 117°05′ to 117°49′ east. It is situated in a warm semi-humid to semi-arid climate zone, where the small amount of precipitation and high evaporation rate facilitate the accumulation of dissolved salts on the soil surface, thus forming saline-alkali lands. Moreover, its location in the North China Plain, with its low and flat terrain, contributes to the convergence of water-soluble salts. Improper irrigation practices, such as flooding irrigation or irrigation without drainage in low-lying areas, can also lead to salt accumulation, causing the rise of the groundwater level and the transformation of original farmland into saline-alkali soil.

Huanghua City has a total land area of 171,800 hectares, of which 90,600 hectares (61,300 hectares of cultivated land) are agricultural land, accounting for 52.75% of the total land area. There are 48,700 hectares of unused land (including 23,300 hectares of saline-alkali soil). The main soil types are fluvo-aquic soil, moisture soil, and coastal saline soil. The total area of saline-alkali cultivated land in Huanghua City is 780,554,749 hectares. In terms of salinization degree, the saline-alkali cultivated land in Huanghua City is mainly classified as light, moderate, and severe (Table 1). Among them, 586,289,665 hectares of the land is lightly salinized, accounting for 75.11% of the total saline-alkali cultivated land; 18420.2 hectares is moderately salinized, accounting for 23.61%; and 996.6 hectares is severely salinized, accounting for 1.28%. The saline-alkali cultivated land is mainly distributed in townships such as Yang'erzhuang Hui Ethnic Township, Jiucheng Town, Qijiawu Township, Changguo Township, and Tengzhuangzi Township.

Table 1- Different Salinized Farmland Areas in Huanghua City

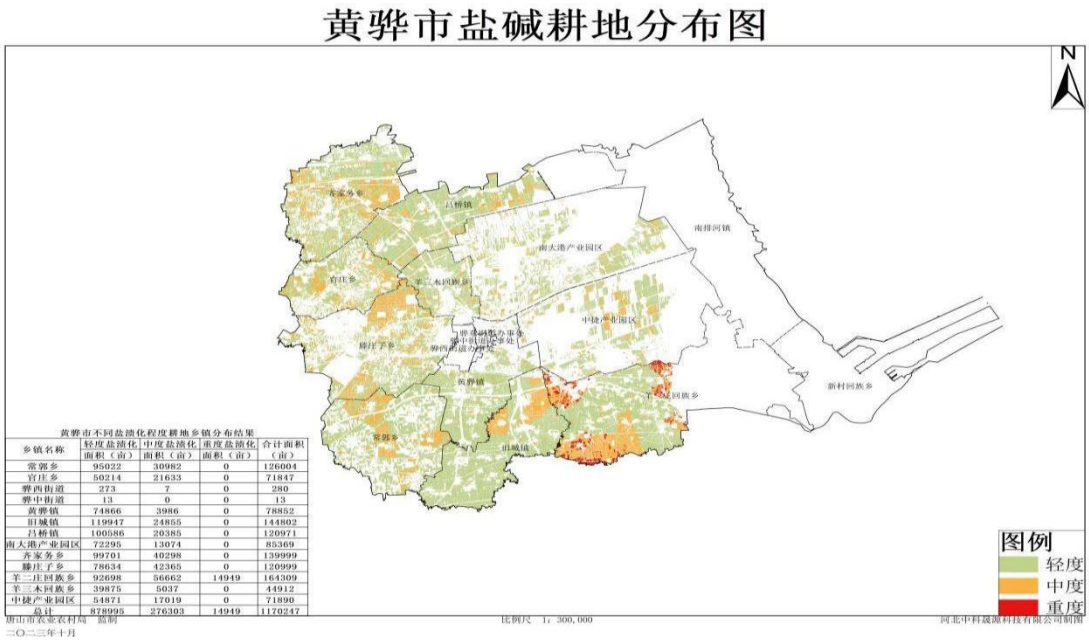
Degree of salinity	Light	moderate	severe	summary
square（MU）	878995	276303	14949	1170247
square（Hectare）	58995.7	18420.2	996.6	78016.5
proportion(%)	75.11	23.61	1.28	100.00

Table 2-Distribution Results of Farmland Townships with Different Salinization Levels in

Huanghua

Names of township	light		moderate		severe		Total	Proportion of each town-ship (%)
	square (mu)	proportion (%)	square (mu)	proportion(%)	square (mu)	proportion (%)	square (mu)	
Changguo	95022	10.81	30982	11.21	0	0.00	126004	10.77
guanzhuang	50214	5.71	21633	7.83	0	0.00	71847	6.14
huaxi	273	0.03	7	0.01	0	0.00	280	0.02
huazhong	13	0.01	0	0.00	0	0.00	13	0.01
huanghua	74866	8.52	3986	1.44	0	0.00	78852	6.74
jiucheng	11994	13.65	24855	9.00	0	0.00	144802	12.37
lvqiao	100586	11.44	20385	7.38	0	0.00	120971	10.34
nandagang	72295	8.22	13074	4.73	0	0.00	85369	7.29
qijiawu	99701	11.34	40298	14.58	0	0.00	139999	11.96
tengzhuangzi	78634	8.95	42365	15.33	0	0.00	120999	10.34
Yang'erzhuang	92698	10.54	56662	20.51	14949	100.00	164309	14.04
Yangsanmu	39875	4.54	5037	1.82	0	0.00	44912	3.84
zhongjie	54871	6.24	17019	6.16	0	0.00	71890	6.14

*1 hectare=15mu



Picture 2- Current distribution map of saline alkali land in Huanghua

(II) Treatment Methods

The improvement of saline-alkali land in Huanghua concludes various factors such as geographical features, salinity level, and land-use patterns. The salinization of arable saline-alkali land in Huanghua City gradually increases from west to east. With issues such as poor soil physical properties, low organic matter content, inferior soil fertility, compaction, poor permeability, limited microbial diversity, poor crop growth, low soil temperature, appropriate methods are taken for improvement. Among the various methods for improving coastal saline-alkali soil, this paper primarily introduces the biological approach using alfalfa.

1.Principles

Salt-tolerant plants can absorb large amounts of soluble salts from the soil and store them in their succulent underground stems and leaves. They also possess the ability to transport salts within their bodies. Many halophilic or salt-tolerant plants possess unique "salt excretion" mechanisms to adapt to high salt threat. And the introduction, domestication, and breeding of salt-tolerant varieties are essential. These plants include Suaeda salsa, alfalfa, Phragmites australis, Salix matsudana, Tamarix chinensis, and other commonly used salt-tolerant tree species. In Huanghua, the biological management of saline-alkali soil focuses on alfalfa improvement under the principles of "ecology, production, and livelihood."

2.Detailed Analysis

(1)Alfalfa

Known as the "King of Forages," alfalfa (Medicago sativa) is a perennial, high-quality legume forage. With moderate salt tolerance, its leaves have the ability to excrete salts, enabling it to grow in saline-alkali soil where a salt content ranges from 0.1% to 0.8%. Alfalfa can also serve as a biological improver for saline-alkali soil, reducing soil salinity and enhancing soil fertility over several years of cultivation.

(2)Alfalfa Planting Strategy

The optimum utilization period of alfalfa is 4-5 years.After this period, crop rotation with winter wheat and summer corn can significantly increase yield (by over 50% on average). However, after two years of crop rotation, soil salinity returns, increasing by more than 40% compared to the previous. While soil fertility decreases significantly, with total nitrogen content dropping by over 60%. Therefore, the maximum years of crop rotation after alfalfa cultivation should be two years, and the optimum is one year. Based on these findings, an "N+2" rotation model of alfalfa+drought alkali wheat+summer corn has been established in saline-alkali land in Huanghua, which involves 4-5 years of alfalfa cultivation followed by two crops (drought-alkali wheat and summer corn). After 4-5 years of alfalfa utilization, the overground parts are cut. Then the remaining plant bodies and roots are deeply plowed two months before drought-resistant wheat planting. This paper selects the experimental field of Namo Farm in Jiucheng Town, Huanghua City, for research and analysis.

table 3-Basic information of the experimental field

project	data/description
Application area	Namo Farm in Jiucheng Town of Huanghua
Application square	6000 mu(400 hectares)
Soil salt content	0.4%~0.5%
Demonstration area of alfalfa+ drought-alkali wheat rotation	1800 mu(120 hectares)
Alfalfa turning and pressing time	The end of August, 2022
Planting time of drought-alkali wheat	The end of Sept, 2022

3.Agricultural treatment Achievements

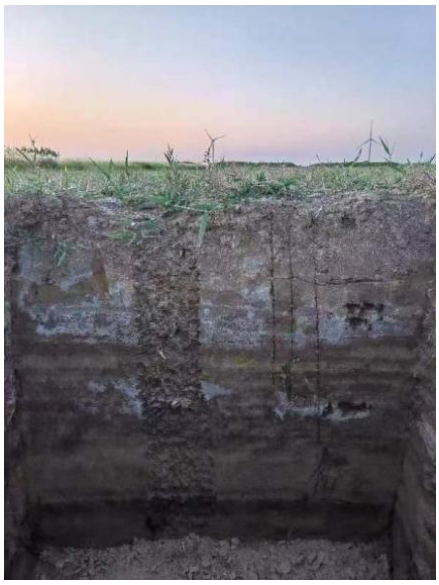
(1)ecological achievement

In terms of ecological treatment, the lush stems and leaves of alfalfa cover the ground, significantly reducing surface evaporation. Meanwhile, the robust roots of alfalfa can penetrate into the soil for over ten meters, breaking down soil capillaries and inhibiting capillary action, thereby reducing soil salinization caused by salt evaporation along with soil moisture. This effectively controls the salt return. Additionally, the roots of alfalfa improve soil permeability, lower the groundwater level, and inhibit the accumulation of the salt on the soil surface during spring and autumn. This not only enhances the utilization rate of saline-alkali land but also allows for concurrent improvement and utilization processes, achieving "improving while utilizing and vice versa." This method has revolutionized traditional physical and chemical treatment methods, which often make the land unusable during the treatment process.

Table 4 Comparison of soil physical and chemical properties before and after improvement

	Before planting alfalfa	After planting alfalfa
Salt content of cultivated	0.42%	0.16%

soil layer		
Organic matter	1.15%	1.36%
Soil alkaline nitrogen content	33.47 mg/kg	47.13 mg/kg
Soil bulk density	1.52 g/ cm^3	1.33g/ cm^3



Picture3- Soil profile map before alfalfa improvement

Picture 4-Soil profile map after alfalfa improvement

(2) Achievements of Crop Rotation on Yield Increase

After four years of alfalfa cultivation, the soil physical and chemical properties of the soil will undergo significant changes. The fertility of saline-alkali low-yield land will increase by 1-2 grades on average, leading to a substantial increase in the yield of drought-alkali wheat and summer corn. Data indicates that this method can significantly increase yields by over 50% on average.

Table 5-Comparison of crop yield before and after improvement

	Original production volume	current production volume	Increase in production percentage
Average yield per mu of drought-alkali wheat	220kg	Over 400kg	≥81.82%
Average yield per mu of summer corn	300kg	430kg	About 43.3%

(3) Auxiliary Achievements

①Agricultural Husbandry Integrated Circular Development Technology Model

A research team composed of the Cotton Research Institute, the Agricultural Resources and Environment Institute, the Dairy Research Center of the Provincial Academy of Agricultural

Sciences, and Hebei Jiuzhi Agricultural Company has screened suitable varieties of high-quality forage crops such as oats, sweet sorghum, silage corn, and alfalfa to establish a technical model of double cropping with oats-silage summer corn and oats-silage sweet sorghum. Additionally, they have developed high-moisture alfalfa+silage jujube powder and an alfalfa+winter wheat+summer corn rotation model, achieving the goal of “promoting animal husbandry through planting and vice versa”.

② Ensuring Nutritional Safety and Adopting an all-encompassing approach to food

As a food which is rich in protein, vitamins, and minerals, alfalfa with large-scale promotion and cultivation is conducive to enriching people's dietary structure and improving their nutritional level, thereby better safeguarding people's nutritional security and adopting an all-encompassing approach to food.

③ Unique Tourism with "Flower Sea- Green Corridor" Alfalfa Fields

With beautiful flowers in yellow, purple, violet, and brown, alfalfa boasts high ornamental value. Based on alfalfa cultivation, the construction of "Flower Sea Green Corridor" alfalfa field tourism services can promote efficient utilization of the alfalfa fields, establishing a unique brand for rural tourism in Huanghua.

④ Supporting the Dual Carbon Strategy

According to calculations, if only 4 million mu (around 266,667 hectares) of alfalfa planting area is added in the coastal saline-alkali land of Hebei Province, the total annual yield of fresh alfalfa can reach 14 million tons, absorbing approximately 2 million tons of CO2. It can also fix 40,000 tons of nitrogen, equivalent to 80,000 tons of urea, which indirectly saves 100 million kWh of electricity for nitrogen fertilizer production and almost 100,000 tons of coal.Over a 5-year utilization period, the total CO2 absorption and nitrogen fixation capacity of 4 million mu (around 266,667 hectares) of alfalfa fields can reach 10 million tons and 200,000 tons respectively. Therefore, the strong carbon and nitrogen fixation capabilities of alfalfa fields are of significant value for green agricultural development and implementing the "dual carbon strategy."

⑤ Establishing a New Format of Green Alfalfa Industry

In the early stages, alfalfa in Huanghua City was mainly processed into dry grass bundles. Since 2018, with the maturity of silage technology, alfalfa silage processing has developed rapidly. Currently, over 70% of alfalfa in Huanghua City is processed into silage (including stretch film wrapping, bag storage, and pile storage). Additionally, the industry of pet-feeding grass, alfalfa grass granules, and alfalfa grass powder are also showing rapid development trends. Companies represented by Huanghua Linjiang Agricultural Technology Development Co., Ltd. have begun to focus on processing industry of alfalfa dishes, alfalfa noodles, and other alfalfa food products. Currently, the alfalfa products in Huanghua City have formed a diversified grass product industry pattern, with alfalfa silage and dry grass bundles as the mainstay, supplemented by alfalfa grass granules, alfalfa grass powder, alfalfa grass blocks, pet-feeding grass, alfalfa dishes, and alfalfa enzymes, etc.

(III) Improvement Measures for Treatment

1. Balanced and Sufficient Development of Resources for Saline-alkali Soil Treatment

Currently, the treatment of saline-alkali soil is continuously improving, yet some issues still exist. The imbalance and insufficiency of resources for saline-alkali soil treatment have become significant obstacles to its further development. During the process of saline-alkali soil

improvement, the disciplinary fields focusing on its comprehensive utilization are concentrated in coastal research institutions and resource and environmental institutes. Existing personnel strength,scientific research platforms, and project funding are insufficient to fully meet the sustainable and stable development of the discipline and the smooth progress of scientific research. Therefore, it is necessary to provide preferential support in the overall planning of scientific and technological resources.

2. Increasing the Proportion of Green Products and Enhancing Brand Influence

Currently, there are not many well-known agricultural brands from saline-alkali soil products in the whole nation and whole province. Some existing brand of saline-alkali soil products are with weak market influence and low popularity. The proportion of green and organic agricultural products from saline-alkali soil is relatively small, and the scale of green production bases is not large. High-quality agricultural products with "two brands and one standard" account for a low proportion. It is necessary to intensify efforts in applying for green and organic agricultural products, as well as in creating and promoting regional public brands, especially in strengthening the creation of the regional public brand "alfalfa silage," to enhance the brand effect of agricultural products from saline-alkali soil in Huanghua City.

III: Transplantation of Saline-alkali Soil Treatment

The above-mentioned measures for saline-alkali soil treatment provide a reference for regions with similar geographical environments. After experimental transplantation in other areas, their feasibility can be verified and promoted accordingly.

(I) Geographical Environment

Located in warm semi-humid to semi-arid regions, coastal agricultural areas need abundant groundwater for irrigation. It results in seawater infiltrating underground and replacing the original fresh groundwater, which leads to an increase in the salinity of the groundwater. During seasonal precipitation, the groundwater level rises, reaching the surface through capillary action. After evaporation, salt base ions remain on the surface, forming coastal saline-alkali soil. As alfalfa can survive in areas with an annual precipitation of over 200mm and grow in high-salinity soil, it is feasible to develop alfalfa for saline-alkali soil improvement in coastal agricultural areas of warm semi-humid to semi-arid regions. Suitable regions include wheat-growing areas in Western Australia and New South Wales, agricultural areas along the Nile River in Egypt, and agricultural areas in central and southern Iraq, etc.

(II) Migration Method

According to the yield and growth of alfalfa, the following migration suggestions are proposed. In areas with annual precipitation ranging from 200mm to 300mm, a mixed grass planting model can be implemented. As a high-quality feed for cattle and sheep, alfalfa can be utilized with the development of animal husbandry. As a result, the land utilization rate can be enhanced and the economic benefits can be improved. Meanwhile, the waste produced by animals during the production process can be returned to the fields,both maintaining soil fertility and providing organic matter, ultimately forming a virtuous cycle. In areas with annual precipitation higher than 300mm or with convenient irrigation, a "N+2" rotation model of alfalfa, drought-resistant alkali wheat, and summer corn can be implemented.

IV: Conclusion

The study reveals that climate, topography, water sources, and human activities in Huanghua region have various degrees of influence on the formation of saline-alkali soil. The biological improvement model of "N+2" rotation of alfalfa, drought-resistant alkali wheat, and summer corn in Huanghua region plays a positive role in saline-alkali soil management, environmental improvement, technological innovation, nutritional security, the development of alfalfa-themed tourism, the implementation of carbon neutrality strategies, and the production of alfalfa silage. Due to its strong plant adaptability, significant effects, and high economic benefits, this model is suitable for promotion in other countries with saline-alkali soil issues. It can be adapted to local conditions, combined with animal husbandry development for mixed planting of grasses, or the implementation of the "N+2" rotation model. In general, developing alfalfa management under the guiding principle of "ecology, production, and livelihood" is conducive to the improvement of saline-alkali soil ecology, economic benefits, coordinated development of multiple industries, and the safeguarding of food, nutrition, and overall well-being for the global population.

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