Ranbir Chander Sobti *Editor*

Role of Science and Technology for Sustainable Future

Volume 1: Sustainable Development: A Primary Goal

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Preface

The Agenda 2030 for Sustainable Development presents a comprehensive plan for achieving a sustainable, prosperous, and harmonious global future. The core of this mission comprises the 17 Sustainable Development Goals (SDGs), which aim to address the fundamental economic, social, and environmental requirements for the purpose of achieving a sustainable future. The SDGs have garnered universal acceptance from United Nations member states, both developed and developing, as well as numerous subnational governing bodies and international organisations. The SDGs embody a pledge, implemented at the national level, to formulate domestic policies and measures aimed at attaining the objectives, alongside frameworks for monitoring and evaluating their advancement. All stakeholders, including governmental bodies, private enterprises, and civil society, bear responsibility for contributing to the achievement of SDGs through their respective roles (United Nations 2015).

Achieving these goals requires the integration of science and technology into development strategies. The pivotal role of science, technology, and innovation in promoting sustainable development cannot be overstated. These three pillars are essential for achieving the SDGs and ensuring a prosperous future for all. Science provides the knowledge and understanding of the natural world, technology offers the tools and techniques for harnessing that knowledge, and innovation drives the creation of new solutions to address the challenges facing humanity.

Science and technology have a critical role to play in sustainable development. They provide the tools and knowledge necessary to address the complex challenges facing our planet, including climate change, biodiversity loss, and resource depletion. By harnessing the power of science and technology, innovative solutions that promote economic growth, social inclusion, and environmental sustainability can be developed. One of the key ways in which science and technology can contribute to sustainable development is by supporting the achievement of the SDGs. The SDGs cover a wide range of issues, including poverty reduction, health and well-being, education, gender equality, clean water and sanitation, affordable and clean energy, sustainable cities and communities, responsible consumption and production, climate action, and life below water and on land. Science and technology can help to address each of these issues by providing the knowledge and tools needed to develop effective policies and strategies. For example, science and technology can help to promote sustainable agriculture by developing new crop varieties that are more resilient to climate change and pests and by improving soil health through the use of precision agriculture techniques. Similarly, science and technology can support the transition to renewable energy by developing new technologies for solar, wind, and hydropower and by improving energy storage systems. In addition to supporting the achievement of the SDGs, science and technology can also contribute to sustainable development by promoting innovation and entrepreneurship. By fostering a culture of innovation and providing support for entrepreneurs, we can create new businesses and industries that promote sustainable development. This can lead to the creation of new jobs and economic growth while also promoting environmental sustainability and social inclusion. In conclusion, science and technology have a critical role to play in sustainable development, particularly in the context of the SDGs. By harnessing the power of science and technology, we can develop innovative solutions that promote economic growth, social inclusion, and environmental sustainability. To achieve the SDGs, it is essential that we continue to invest in science and technology and promote their integration into development strategies.

The present book in two volumes is **ROLE OF SCIENCE AND TECHNOLOGY** in sustainable development is compilation of some of the issues.

It covers the role of traditional and emerging areas of science, technology, and innovations in meeting the goals envisaged in SDG document with particular reference to India.

The chapters have been contributed by experts in their respective fields.

The editor acknowledges the help rendered by his wife Dr. Vipin Sobti, daughters Er. Aditi and Dr. Aastha Sobti, son-in-laws Er. Vineet and Er. Ankit, and of course the critical but encouraging words of granddaughter Irene in the preparation of the books. The heavenly blessings of parents provided enormous energy in planning and completing the project.

Chandigarh, India Ranbir Chander Sobti

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Ranbir Chander Sobti is an emeritus professor at Indian National Science Academy (INSA) and a senior scientist at Punjab University, Chandigarh, India. He is a former vice-chancellor of Panjab University, Chandigarh, and Babasaheb Bhimrao Ambedkar University (Central University), Lucknow, India. He started his career as a cytogeneticist and then moved on to molecular biology, including genomics, to understand the susceptibility and disease process of cancer, COPD, AIDS, metabolic syndrome, and kidney diseases. He has also used stem cells and nanoparticles to understand the process of tissue organ development through a designed de-cellularization protocol. He has published numerous research articles in journals of international repute and has also published more than a lot of books. He is a fellow of the Third World Academy of Sciences, National Academy of Sciences, India, Indian National Science Academy, National Academy of Medical Sciences, National Academy of Agricultural Sciences, Canadian Academy of Cardiovascular Diseases, and a few others. He was the general president of the Indian Science Congress for the 102nd session held at the University of Jammu in 2013. He is the recipient of many prestigious awards like the INSA Young Scientist Medal, UGC Career Award, Punjab Rattan Award, JC Bose Oration and Sriram Oration Awards, and Lifetime Achievement Awards of the Punjab Academy of Sciences, Zoological Society of India, and the Environment Academy of India. The Government of India bestowed upon him the honour of "Padma Shri" in 2009 by way of rightfully acknowledging his great contribution to higher education in India. In 2016, he was also honoured with the "Bharat Gaurav", Lifetime Achievement Award at the House of Commons, British Parliament, London, UK.

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Part I

Pillars of Sustainability: Present Scenario in India

Science, Technology and Innovation for Achieving Sustainable Development Goals

R. C. Sobti and Aparna Sarin

Abstract

In the emerging global scenario, science, technology and innovation (STI) have been identified as key factors for sustainable and comprehensive growth. For achieving the multidimensional development as well as meeting the Sustainable Development Goals (SDGs) by 2030, all member states have adopted STI as a vital component of their national strategies. Emphasis is on finding new methods and creative solutions for attaining economic and social gains without compromising the environmental impacts of developmental activities. These methodologies should be designed keeping in view the different cultural, societal and organizational differences in which they would operate. For achieving SDGs, state-specific STI policies can play an important role in implementing practices of good governance, well-structured rules and a comprehensive legal framework. Formulation and efficient implementation of these policies can successfully address the unique challenges that lie at the heart of achieving the SDGs.

Keywords

Sustainable Development Goals (SDGs) · STI policy · Innovation · Targets · Intellectual property right (IPR)

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1 Introduction

Through the course of human history, progress of any nation has been defined by advancements made in the major domains of science, technology and innovation. Technological advancements have resulted in dramatic increases in growth and productivity. Stark contrasts can be observed between countries that experienced these revolutions and the rest of the developing world. However, these revolts have been achieved at the cost of putting additional pressures on the environment, upsetting traditional lifestyles and creating disparity between nations. Gradually, it was globally realized that the social and environmental factors also need to be considered when formulating strategies for development. Thus, the notion of sustainable development was perceived. The guiding principle of sustainable development is that the present needs of meeting human development goals are met in such a way that they do not compromise the resources for future generations to meet theirs. This requires deep understanding of interrelationship between the economic, social and environmental factors and maintaining their delicate balance.

1.1 What Are Sustainable Development Goals (SDGs)?

Since the 1992 Rio Conference, the environmental impact of development has been at the top of the agenda and major steps have been taken at national as well as global levels. The Millennium Declaration was issued by the United Nations in 2000 with a strong development agenda centred around the MDGs. The final document of Rio + 20 Conference of 2012 was 'The future we want'. It brought forth the concept of universally applicable Sustainable Development Goals (SDGs) that all countries should strive to achieve. The 2014 United Nations report on 'The Road to dignity by 2030' called for 'historic action' to 'change lives and safeguard the planet'.

The year 2015 was an eventful year marked by three major events: the Addis Ababa Conference on "Financing for Development" (July), the UN Special Summit in September identifying 17 goals and 169 targets[1] (230 indicators) to be achieved by 2030 and the COP21 Conference on Climate Change at Paris in December (Giovannini and Roure 2017). The SDG agenda called on all countries to improve their scientific studies, advance technical competences, promote a culture of new inventions and enhance community and private venture (Giovannini et al. 2015).

The SDGs are 169 objectives that seek to accomplish a healthier and more supportive world for everyone through a system of fundamentally interdependent and interactive goals. There are two kinds of interactions: positive and negative interactions. In other words, progress towards one of the SDGs will influence progress towards others. The SDGs have been adopted by all the members of the United Nations (UN), viz. advanced and developing nations, sub-national entities and international organizations. Science, technology and innovation (STI) have long been recognized as major contributors for increased production, economic progress and social well-being. However, for realizing the goals of sustainable development, STI have acquired even greater importance. The 17 SDGs include eliminating poverty;

no hunger; good health; providing quality education; ensuring gender equality; clean water and sanitation; affordable and clean energy; decent work opportunities and economic growth; improving industry and infrastructure; reduction of inequalities; self-sustaining cities and communities; responsible behaviours in consumption and production; climate action; life below water; life and biodiversity on land; peace, justice and strong institutions; and partnerships for achieving goals.

2 Role of Science, Technology and Innovation in Sustainable Development

The science, technology and innovation (STI) potential of a nation is critical not only for its financial growth but also for fulfilling the basic needs of safe food, quality healthcare and high-quality education and mitigating the adverse effects of environmental changes and disasters. Science has a major contribution in responding to the challenges of sustainable growth as it provides the basis for innovative paradigms, explanations and knowledge for identifying, clarifying and addressing global issues for the future. The solutions achieved through scientific research can be tested and replicated and thus provide the foundation for robust policymaking and impact analysis. From the view of study and operation, science ranges from natural processes and their human consequences to social systems, impact on health and well-being and ways to enhance subsistence and livelihoods to meet the ultimate objective of poverty alleviation (UNESCO 2014).

It plays a substantial role in responding to the sustainability challenge that the world faces today, but they also need to be seen in the light of the wider context in which they operate. It is important to recognize that while the world is facing a lot of challenges which are similar across different countries, there are also certain differences amongst them. Hence, knowledge systems should be designed broadly to incorporate the various features of each country such as its antiquity, organizational and sociocultural aspects. The contribution of knowledge, skill and innovative ideas to a new model of holistic development necessitates a deep comprehension of the relationship between these three pillars. It is equally important to also recognize that any damage to environment ultimately harms financial growth and social welfare, particularly for the weaker and deprived sections of society. In addition to the technical sciences, other domains such as social and economic sciences also play a crucial role in improving living conditions; promoting judicious consumption; improving production practices; highlighting issues of ecological deterioration, scarcity and inequality; and promoting harmony and safety.

All regions of the world are experiencing effects of changing climate and are witnessing erratic weather events. Geography plays an important role in climate change, and as a result, the ecological effects will be variable in different areas. Also, the overall development levels, preparedness and mitigation strategies would be defining factors for any country or community's response to ecological and financial impacts of such challenges. One of the biggest challenges in the scenario of climate change is promoting and developing mitigation as well as adaptation strategies. In today's globalized world, due to increased resources the movement of goods and people across borders has caused global challenges such as global warming, climate change, infectious diseases, loss of native biodiversity, extinction of plant and animal species, etc. to reach critical thresholds. While there has been a lot of focus on mitigation measures, especially for greenhouse gas (GHG) emissions, there has been little or no focus on promoting and developing adaptive technologies. Transformative changes can only be achieved by developing low-carbon technologies and making them economically reasonable and easily available. Inconsistent weather conditions are leading to increased incidences of cloud bursts, forest fires, excessive rainfall and drought in ecologically fragile areas of the world. Through acquired knowledge, several indigenous communities have developed small-scale technologies to efficiently use scarce water resources and combat flooding after excess rainfall. These measures work well in local contexts but for large-scale operations inputs from latest scientific knowledge are critical. While vaccines and antibiotics have kept infectious diseases under control for decades, the world faces an unavoidable increase in antimicrobial drug-resistant pathogens. Now, there is room for innovation, the transformations required cannot be accomplished by engineering or technology alone. Strengthening the scientific, technological and innovation capabilities and their effective integration into economic activities are key elements in broadening a nation's capacities and advancing sustainable development (Anadon et al. 2016; Brooks 1980; Lundvall 1992, 2010).

New technologies have opened wider markets and increased jobs avenues in diverse sectors such as information technology, agriculture, healthcare, medical diagnostics, renewable energy, pharmaceutical sciences, drug discovery, etc. Easy access to ICT has caused improvement in the living standards of people living in remote regions by enabling better communication, acquiring knowledge and handling their enterprises with greater efficiency. Technological interventions have tremendously contributed towards increasing agricultural yield directly improving the economic status of families. In areas facing adverse climatic conditions, latest researches in fields of biotechnology such as drones and drip irrigation through sensors are helping farmers in improving yields and livelihoods. Lately, upcoming technologies are trying to address issues of curbing detrimental gaseous emissions and enhancing energy-efficient vehicles in manufacturing industries.

Several novel technologies are currently in varying stages of deployment and hold significant promise for addressing challenges of the developing world. A few of the emerging technology areas, though having substantial overlap, with realistic potential to achieve SDG targets within the 2030 timeframe and beyond are described below:

1. **The Internet of Things, artificial intelligence and Big Data analytics:** They have the potential to enhance learning outcomes through personalized e-learning approaches, agriculture, health and medical diagnostics (Hamet and Tremblay 2017), improving water, environment conservation, improving water security and access to clean energy. In the healthcare sector, sensor-based IoT wearables and tracking devices are routinely being used to address immediate health threats and cold chain network management for vaccines. Smart agriculture is now getting scientific inputs from IoT-based devices on the moisture content of soil, pH

level, nutrient profile and atmospheric conditions. This data is very helpful in planning agricultural activities including irrigation and using fertilizers. It can also be used for sensing and documenting sources of land and water pollution thus enhancing water and food security.

2. **Robotics:** Its application areas include robotic surgeries in big hospitals, rescue operations in disaster-hit areas, spraying pesticides in agriculture fields and automated harvesting and packaging.
3. **Blockchain and distributed ledgers:** This can be used to create digital identification systems, as well as for decentralization and integrity in finance and logistics. Blockchain technology can also be used to control and verify electoral processes, as well as to increase the transparency and authenticity of land title transactions.
4. **Genetic editing and CRISPR:** The ongoing researches in genetic engineering and CRISPR technologies have the potential to develop personalized medicines, environment-resilient crop and animal varieties thereby improving food security and reducing environmental threats like disease vectors.
5. **Nanotechnology and nanomaterials:** New nanomaterials can treat water from contaminants such as salt and arsenic, purification and desalination of non-potable water with graphene, increased access to energy through their use in photovoltaic collection and storage batteries and for combating cancer and other diseases.
6. **Drones and remote sensing:** One of the main benefits of these technologies is that it is a non-intrusive tool with the ability to make repeatable, objective measurements that allow for a more balanced and just decision-making. Satellites orbiting in space, with specialized sensors, can cover large and remote parts of the Earth. With over 50 years' knowledge based on RS and GIS data, we now have a better understanding of the atmospheric, land, ocean and ice-covered areas of the Earth.

3 Harnessing the STI Potential for Achieving SDGs

Application of science, nurturing innovation and formulation of policies to this effect have been emphatically voiced under various goals and targets of the SDG framework (Hajikhani and Suominen 2022). Through evidence-based knowledge acquired during the processes of production and dissemination, STI has the potential to identify challenges and offer possible solutions to tackle the challenges associated with each SDG. Recently, during the COVID-19 pandemic which hit the entire globe, innovative technologies played a significant role in managing and containing the spread of disease. The use of new technologies for the development of vaccines, software applications for keeping patient records, molecular biology-based testing techniques and data analytics formed the backbone of policy decisions.

STI encompasses acquiring knowledge of fundamental processes, its application and improvement of existing methods for social and financial benefits. These three areas are interconnected in many ways and comprise of several actors who interact with one another in certain ways. A well-structured STI system is made up of several actors, divided into sections or subsections, with important interrelationships. A thorough understanding of all three components is essential for addressing issues in a holistic and systematic manner. For instance, some useful innovations based on new technologies may initially radically alter the dynamics of the social, physical or ecological systems. But few years later, they may raise new scientific issues which may then be the driving force for opening new avenues for developing knowledge by scientists and researchers working in scientific research organizations, research centres, universities, academies or professional societies. Thus, the new evolving situations call for developing newer products or technologies. Better methods of producing or utilizing goods and services are developed by industry leaders, entrepreneurs, farmers and individuals stimulating a surge in innovations. Innovators are inspired to create novel goods, services and processes by scientific and technological advancements. The actors of each section/subsection profit from their interactions. For creating new knowledge, applied scientists and engineers benefit from ideas and feedback from market needs, private businesses, consumers and product developers. In every flourishing economy, innovation has always been at the core of development. In the long run, betterment of lifestyles and increase in per capita income have been driven by productivity changes closely related to technological advancement and innovation.

4 Challenges in Achieving SDGs

The 2030 agenda was framed promising a better future for mankind, but is facing several challenges. The implementing countries differ greatly in terms of their capacity, socio-economic resources and technological advancements. This inequality hinders the implementation of the SDGs around the world, questioning the commitment of leaving no one behind. The massive economic slowdown during the COVID-19 pandemic has contributed considerably to the decline in achieving SDG targets that were adopted in 2015. The increasing numbers of extreme weather events and frequent disasters across the planet are posing serious threats to global food security and biodiversity loss. As per the available statistics of May 2022, approximately 41% of 230+ indicators for 17 SDGs lacked sufficient data. There is an urgent need to combine statistical and spatial data for scientific decision-making in several countries (Guo et al. 2022). Some other barriers that have been identified include the availability of reliable data, lack of political will, lagging technical know-how, inadequate financial resources, gender inequality, etc.

5 Building STI Capabilities: Role of Governments

In essence, growth of a country is a continuous process of building capacities of its people. Governments play a critical role in building scientific temperament, instituting scientific studies and improving the innovation capacities of its people, expanding the network of academic institutes, supporting education and research infrastructure and designing and implementing nationally relevant industrial policies. There are strong evidences that show that the innovation capacities of any country are proportional to the investment in its scientific pursuits. The structure, functioning and quality of the educational system play an important role in the transition of economy levels. In this context, the pool of scientists and researchers are an asset of any country and supporting their training and assisting their inter-institutional mobility are key to faster transfer of education and skillsets. While in advanced countries, governments still allocate a substantial amount of funds for studies for advancement in various sectors including defence-related areas, the developing countries, instead of investing heavily in research, adopt technologies available elsewhere only after they become industrial standards. Where private capabilities are low, the government sector is taking the charge of establishing new industries. However, in countries where private players are strong, their participation and collaboration has assumed great significance and they are the ones taking lead in technological breakthroughs.

6 Importance of Policy Space for Science, Technology and Innovation

The national priorities and social requirements of any country keep changing from time to time. To keep pace with dynamic economy, the policymakers adopt measures to align S&T needs by incorporating emerging technological trends (United Nations 2022). A coherent policy for finding solutions to societal issues while facilitating innovation and addressing job/wealth creation are significant aspects of STI policy. These policies are the cornerstone of development strategies of many countries. The designing, implementation and monitoring of such policies demand deep understanding of each country's scientific capabilities, infrastructure and linkages, advantages and disadvantages and its relation to other developmental policies. As a result, these policies come to the centre stage due to far reaching implications and become highly nation specific (UN IATT on STI for the SDGs 2020; Edquist 2004).

The primary objective of STI policy requires addressing some of the systemic failures and bottlenecks that prevent learning and innovation by inhibiting the performance of innovation systems (Weber and Rohracher 2012; OECD (Organisation of Economic Co-operation and Development) 2011). Following are some of the system failures that have been identified:

1. Infrastructural failures: inadequate physical and scientific and technological infrastructure (information technology, telecommunications, roads, etc.)
2. Institutional failures: the absence or abundance of regulatory and legal issues (intrinsic institutional failures) and the existence of informal institutions which impede innovation.
3. Network failures: existence of strong links and intensive collaboration that resists appreciation of new ideas and weak knowledge exchange.
4. Skills failure: lack of ability to learn quickly and efficiently, incapacity for developing new technologies.

5. Policy coordination failure: the lack of policies for effective coordination across various levels, sectors, systems, policies, ministries and institutions.
6. Demand articulation failure: lack of knowledge about market needs of users and scope for improvements.
7. Reflexivity failure: absence of an effective impact-assessment mechanism to design adaptive policies.

6.1 Major Stages and Guiding Principles

The implementation of STI policies can be supported through dedicated SDG Roadmaps. In theory, the STI policy cycle follows a well-defined linear order. However, in practice, many of the policy cycle phases can occur at the same time. Broadly, it includes formulating a comprehensive action plan by developing a vision based upon thorough understanding of existing gaps and future needs with a scope for assessment and improvement by adopting alternative strategies. Some fundamental principles which can significantly improve effectiveness of STI policy cycle include:

(a) Directionality: Setting up clear and well-defined objectives can galvanize participation of diverse beneficiaries including researchers, innovators, government leaders, civil society, etc.
(b) Use of evidence, experience and foresight: A study of existing knowledge and technologies available elsewhere can help in avoiding duplicity of efforts, increasing accuracy of processes and reducing market failures.
(c) Diverse stakeholder base: Implementation of STI policy would require involvement of various agencies and departments. Participation of multi-sectoral experts during formulation would reduce the chances of missing out any important issues.
(d) Learning and experimentation: Instead of being a one-time effort, STI policy-making is a continuous and evolving phenomenon. With changing requirements, there would be always new factors and their interrelationships would decide the course of strategies to meet new challenges and needs through new knowledge, methods of testing and advancement.

6.2 Regulatory Framework

Implementation of policy is an administrative procedure involving resources, governance, political will and decision-making. During this phase, policy instruments are put to the test as policymakers validate whether stakeholders support the instruments as designed and report any practical impediments to its implementation. It also involves social and political factors, such as beneficiaries, bureaucracy and social groups. Monitoring and appraisal form the last but important step of the policy cycle. The primary purpose is to critically monitor progress on the implementation of policies and to collect evidence of achievements and difficulties in achieving the key objectives of a country's STI policy. Such evidence-based policymaking is crucial in studying the effectiveness of interventions, improving the policy objectives by adjusting the existing instruments and selecting best alternatives for policy redesigning.

7 India's Space Program: Major Milestones and Its Role in SDGs

The Indian space industry has witnessed significant growth in recent times. The Indian Space Research Organisation (ISRO) successfully achieved controlled landing of the Chandrayaan-3 on 23 August 2023 near the moon's south pole making India only the fourth country to do so. With this, new frontiers for science and engineering have opened to study polar ice and the chemistry and mineralogy of the moon's rocks and dirt. In the future, the polar ice may be a potential source of rocket fuel for future lunar missions. India launched a rocket to explore the Sun on 2nd September 2023, just over a week after successfully landing an unmanned spacecraft on the moon. The Aditya-L1 rocket, which carries scientific instruments, is on a 4-month mission to study the outermost layers of the Sun. Understanding the Sun's intricate magnetic behaviour is essential for improving space weather prediction, safeguarding technological assets and unravelling stellar evolution. India is planning to send a 3-day, crewed mission into Earth's orbit by 2024.

ISRO has been continuously achieving milestones, one after the other. To mention a few recent ones, the Chandrayaan-2 launched in 2019 continues to study the lunar surface, while the Chandrayaan-1 launched in 2008 helped confirm the existence of water on the moon. In 2017, ISRO's Polar Satellite Launch Vehicle successfully launched a total of 104 satellites. In 2014, India became the first Asian nation to put a craft into orbit around Mars.

8 Role of Space Technology in Achieving SDGs in India

Space technology has been providing solutions to nearly all areas of life, from education, healthcare and agriculture to biodiversity conservation. Space exploration is a flourishing sector and with the entry of private entities, employment opportunities and start-up registrations will increase. Some significant roles are listed as below:

- High-resolution georeferencing maps are used to ascertain the location of health clinics and schools particularly in rural areas. This is an effective way of analysing the impact of governmental policies in reaching out to the far-flung areas.
- Space technology and data solutions are being utilized in government projects in horticulture and agricultural, e.g. FASAL, CHAMAN and NADAMS Projects.
- Telemedicine has proven to be the fastest and most effective solution, especially during the COVID-19 pandemic. Space technology is being used to monitor the air quality index and smart wearable devices for tracking physical activity are very popular nowadays.

- The EDUSAT and GRAMSAT satellites are being used for education in the rural areas of India. High-speed Internet connectivity is complementing online education and ICT-based education programs and developing skills in technologies like AI and VR.
- Geospatial and remote sensing technology is increasingly finding use in water management and cleaning of polluted rivers.
- In collaboration with the Department of Urban Development, ISRO has developed a GIS database-design standard document for the AMRUT cities. The Bhuvan Geo-Platform maps assets and tracks schemes which can be accessed by smart city planners.
- GIS is being utilized to map natural resources, seasonal and monthly variations, food supply chain, forestry management, wildlife trafficking, local tourist places using augmented reality (AR) and virtual reality (VR), waterfalls, treks, etc.
- Geospatial information is the most accurate and precise way to map climate variability by providing data on groundwater, depleting snow cover, tracking vessel movement in oceans, oil spills and wetland management.

9 Conclusions

The 2030 Agenda for Sustainable Development has envisioned science, technology and innovation as fundamental components of sustainable development strategies. There have been concerted efforts for raising awareness about their integration into the national development strategies and technological transition in the developed and developing nations (United Nations 2021). This has shown results in achieving some of the SDG targets such as eradication of poverty by providing opportunities for livelihood. This recognition of strategic nature of STI as a powerful driving force of economic change can become a basis for strengthening of international cooperation for developmental programs and extrabudgetary provisions for addressing today's challenges. Thanks to the efforts involved in this process, there has been significant economic and social progress in several continents, although the environmental impact of this development has been immense. Today's cutting-edge technologies and innovations, therefore, need to support all three facets of growth, viz. social, economic and environmental. Relatively simple changes such as effective governance, protection of intellectual property rights, strengthening technology extension services, facilitating collaborations, promoting entrepreneurship development and implementation of STI policy recommendations within the time framework can deliver positive outcomes.

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Sustainable Development in India and Its Future Prospects

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Abstract

The importance of science and technology (S&T) in understanding the roots of sustainability concerns and developing effective solutions is becoming more widely acknowledged. The CFCs used for food preservation, air-conditioning, and ozone depletion were all made possible by scientific and technological progress. In addition to raising the ozone alarm through study and monitoring, they also provided us the alternative technologies that have allowed us to keep fulfilling the demands that CFCs have served in a less harmful manner to the environment. The rise in agricultural yields and improved distribution networks that have kept much of the world from starvation are largely attributable to scientific and technological advancements, but they have come at the expense of severe environmental damage.

In the twenty-first century, fostering sustainable transitions will need for a wide range of measures, not the least of which is better science and technology development and application.

Keywords

Sustainability · CFC · Biodiversity · Environment · Technology

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1 Introduction

Since the publication of Our Future Together reports by the Brundtland Commission in 1987, sustainable development has been a topic of discussion around the world. As per the report, "Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet" were the three grand challenges facing the international community at the beginning of the twenty-first century. Many international, regional, national, and municipal agendas now include sustainability as a "high table" subject. Although different people in different places have different ideas about what sustainability entails, there is now widespread consensus that one of its primary objectives should be to encourage a shift in development toward strategies that provide for human needs while protecting the planet's sustaining ecosystems and reducing the prevalence of extreme poverty and food insecurity. To this end, we need models of governance that not only give citizens more agency but also take into account the demands of future generations (InterAcademy Panel 2000).

2 Role of Science and Technology for Sustainable Development

2.1 Past Contributions

Through the collaborative process summarized above, a wide range of S&T contributions to sustainable development around the world were highlighted. Climate and ozone layer changes, for instance, pose social, economic, and environmental risks that have been quantified by scientific measurement and analysis. At its finest, the Consultative Group on International Agricultural Research (CGIAR) has developed and deployed regional crop breeding and testing systems that combine conventional farming methods, traditional agricultural expertise, and cutting-edge breeding techniques. The GIS-based data system developed for Mexico by the National Commission on Biodiversity (CONABIO) has improved the country's ability to self-assess its biodiversity and to provide a variety of decision-support services to its residents, businesses, and other stakeholders. The Azraq Oasis Conservation Project in Jordan is representative of many similar initiatives that have been successful at the local level by rehabilitating damaged land systems to a point where they can once again sustain both nature and society using a combination of traditional wisdom and cutting-edge technology (Kates et al. 2001).

2.2 Near-Term Prospects

Our consultation findings point to a wide variety of science and technology-based activities that, if pursued aggressively over the next 5 years, might produce measurable gains in local and regional sustainability. The generation of new knowledge is one of these activities, while the improved and more widespread use of existing information is another (IGBP 2001). Consultation with affected stakeholders working for a sustainable development action plan needs to be done on priority to initiate the process of susceptibility. The examples below illustrate the spectrum of contributions that can be fairly expected from the S&T community over the next 3 years.

(a) The capacity to predict abnormal climate conditions a few months in advance has emphasized the possibility of considerably reducing the susceptibility of agricultural and water systems to drought. The preliminary steps have demonstrated that integrated application and usage programs must be built concurrently in order to fully fulfill this potential.
(b) European purchases of tropical hardwoods have decreased as a result of "eco-labeling" and other certification initiatives. The success of such initiatives is tied to the trustworthiness of the certification procedure as a whole, as well as the promotion of the certified product. A variety of biological resources and production systems may benefit from the early triumphs seen with forest products, coffee, and other crops.
(c) The importance of taking a holistic view of systems, where production and consumption may be located on opposite sides of the globe, in designing more sustainable practices in today's rapidly globalizing world cannot be overstated. Such comprehensive assessments can provide society with a far broader and presumably more effective and equitable variety of options, as demonstrated by a pilot analysis of aquaculture systems in Thailand (IGBP 2002).
(d) The Scolel Té project in Chiapas, Mexico, demonstrates how knowledge gained from developing effective agroforestry programs may be applied beyond local contexts to benefit society as a whole through the provision of carbon sequestration services and the promotion of sustainable rural livelihoods.
(e) Transitioning to sustainability will require a lot of innovation, most of which will come from grassroots organizations and small businesses that cannot afford their own research and development labs. Efforts in India demonstrate how much can be accomplished with even little public backing of networking and R&D facilities.
(f) The predicted doubling of the world's urban population within the lifespan of today's young professionals represents one of the most significant problems, as well as one of the most exciting prospects, for a transition to sustainability. Emerging perspectives on cities as self-organizing, dynamic, adaptive systems have far-reaching consequences for governance and policy. The S&T community may provide data sets, visualization tools, and scenario development techniques to help catalyze relationships between researchers and change agents from different locations.

2.3 Future Constraints

There is one success story of how science and technology have been used to advance sustainable development for every ten failures and missed chances. In contrast to the decades of progress in documenting the state of human development, still accurate data on the biodiversity and ecosystem of the world is unavailable (Mabogunje 2001).

When it comes to certain dangers to sustainable development, science and technology could be useful but have not yet been mobilized to the cause. The lack of emphasis on experimental learning and ecological consciousness within global educational systems has led to a significant reservoir of untapped information among individuals who play a crucial role in facilitating the transition toward sustainability. Much research and technology that could be useful is painstakingly developed but is never used.

There are not nearly enough resources dedicated to sustainability challenges, including insufficient funding, a lack of qualified scientists and engineers, and inadequate infrastructure to carry out the work that needs to be done. The potential for S&T to aid in a transition toward sustainability will remain unrealized unless these limitations are lifted. Next, we will discuss how our discussions have led us to believe this can be done.

3 Sustainable Development, Cutting-Edge Research, and the Quest for a "New Contract"

Despite general agreement on the need of science and technology for long-term growth, a significant gap exists between what the S&T community believes it can provide and what society has actually demanded and paid. In light of this disparity, the S&T sector is increasingly calling for a "new contract" between research and society for long-term progress. The agreement states that the S&T sector will devote an increasing share of its resources to research and development agendas that reflect socially determined goals of sustainable development. In exchange for this promise of improved social, economic, and environmental conditions, society would commit to invest sufficiently to allow science and technology to contribute. Our conversations highlighted a set of tangible activities that the S&T community must take in order to make the "contract" idea a reality (ICSU 2002a).

4 Boosting Both S&T Supply and Demand

The "demand" and "supply" sectors of science and technology for society development will need to shift in order to make the "new contract" a reality. Growing public and political understanding of the complexity of sustainability transitions is essential to meeting the growing demand for S&T. It will also need convincing the public that the S&T community can be relied upon to provide solutions and boosting the volume of contributions made by that group. The capability to increase their contributions sufficiently to meet the scale of the sustainability challenges will have to be built. The corporate sector, the public health sector, and semigovernment organization will all need to work together on a common problem. Challenges to sustainability can only be overcome with the help of indigenous and traditional knowledge.

The establishment of a robust and extensive communication channel between the science and technology community and those dedicated to addressing sustainability