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Examining the Position and Role of Biotechnology in the Development of International Environmental Law

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Abstract: By protecting biodiversity and developing solutions—including those for removing pollutants from water, soil, and air—biotechnology has enabled the use of biomass and biodiesel for fuel production. Additionally, by creating a basis for extracting genetic material from the remains of extinct plant and animal species to simulate extinct or endangered species, it has laid the groundwork for the development of international environmental law. This can significantly contribute to the advancement of international law in this area, particularly by providing alternative mechanisms to traditional methods of preventing and addressing environmental degradation.

Despite the substantial role of biotechnology in the development of international environmental law, the emergence of unknown toxic compounds, allergic reactions, and unpredictable genetic contamination—resulting from the introduction of modified organisms into ecosystems—may also contribute to further environmental degradation or contamination. Nevertheless, both the positive impacts of this technology and its potential harms have been key factors in shifting the international community's perception of the importance of environmental protection. This shift has ultimately accelerated the process of developing and codifying international environmental law more extensively than before.

In this article, by examining both the benefits and risks of biotechnology, we aim to explore how it can be utilized to advance international environmental law. In this regard, while the positive aspects of biotechnology should be acknowledged, it is equally important not to overlook its potential consequences and side effects.

Keywords: *Environmental strategies, principles of international environmental law, sustainable development, international law, biotechnology.*

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Introduction

The remarkable transformation in human access to modern knowledge is a defining feature of the twenty-first century. This transformation, alongside advances in science and technology, has significantly influenced contemporary international law. Undoubtedly, new scientific developments in the international community have introduced new domains into the field of international law. However, this rapid progression—while enabling the acquisition of modern technologies and the production of more advanced goods and services—has also brought about various negative and unintended consequences.

International environmental law, as a relatively new branch of international law, is particularly affected by technological developments. It faces some of the most destructive and undesirable consequences, especially since many of its obligations remain soft law—that is, non-binding or only loosely binding in nature. The ongoing degradation and pollution of the environment, along with the growing need to prevent environmentally harmful activities, have created a foundation for a serious shift toward new technologies such as biotechnology. This shift aims to strike a balance between the exploitation of natural resources and environmental preservation.

Biotechnology—defined as *"the intelligent intervention of humans in nature to improve and provide various products by manipulating and utilizing the molecular structure of plant and animal species"*—is still in its early stages. Nevertheless, it holds the potential to significantly reshape environmental conditions.

The use of biotechnology in removing pollutants from water, soil, and air, and in producing biofuels to support biodiversity, positions it as a promising tool in the effort to prevent environmental degradation. However, this relatively new technology also has the potential to cause undesirable and irreversible consequences if misapplied or unregulated.

The introduction of biotechnology into international environmental law can be seen as a starting point for the legal examination of its implications on the environment at the international level.

Biotechnology stands as one of the most significant pillars of scientific, social, and economic development for countries across the globe. Its advancement is now regarded as a key indicator of national progress.

In the twenty-first century, biotechnology has expanded to such an extent that it has deeply influenced nearly every aspect of human life—ranging from the environment to the economy, industry, agriculture, and food security. It has offered solutions for conserving food resources, reducing environmental pollution, increasing and enhancing agricultural productivity, and decreasing reliance on chemical inputs in farming, all while contributing to cost reduction.

1. Definition of Biotechnology

Several definitions have been proposed for biotechnology. One such definition describes it as *"the science of using microorganisms for human benefit"* (Mahboodi, 2000:9). The World Health Organization defines biotechnology as:

"Biotechnology includes all methods that use living organisms or their parts to produce, modify, or alter products to improve and optimize plants and animals or to produce microorganisms for specific applications."
(Yosef Touret, 2011:12)

Similarly, the National Biotechnology Document defines it as *"the intelligent action of humans in nature with the aim of improving and producing various products by interfering with and exploiting the molecular structure of plant and animal species."*

Potential Benefits and Risks of Biotechnology

Historically, biotechnology was primarily used in the food industry, with early applications in the production of fermented beverages and bread. However, today, its applications extend far beyond food and pharmaceuticals. Biotechnology now plays a crucial role in waste treatment, environmental pollution reduction, and the production of renewable energy sources (Smith, 2004:27).

With the rapid increase in the global population, concerns over food production and distribution have intensified, highlighting the need for comprehensive strategies in this field (Nzhendimanesh & Eskanderzadeh, 2005). Biotechnology offers significant potential to enhance food production, both in terms of quantity and quality. Traditional plant breeding methods alone can no longer meet the nutritional needs of the growing human population. However, by combining traditional breeding with biotechnological techniques, it is now possible to improve the quality and efficiency of nutrient production (Dehnad & Hajizadeh, 2013:121). Soil conservation is particularly critical for ensuring global food security. In this context, researchers from the University of Sheffield (UK) reported in 2015 that one-third of the world's fertile soil has been lost over the past 40 years due to erosion and pollution (Milman, 2015, *The Guardian*). Biotechnology can help address this crisis by developing plant varieties resistant to environmental stressors such as nutrient-deficient soils.

Through genetic modifications, biotechnology enables the enhancement of certain traits in animals and plants, such as increasing vitamin content or nutritional value (Ahmadikhawah, 1998:3). It also aids in managing environmental stresses (Dehnad & Hajizadeh, 2013:131), which is vital for preserving ecosystems, particularly forested areas that are vulnerable to degradation.

Potential Risks and Environmental Concerns

Despite its many benefits, biotechnology also presents significant risks. If misused, it can have harmful and irreversible effects on both human health and environmental sustainability (Mahboodi, 2000:11). The application of biotechnological products in agriculture can disturb the natural balance of ecosystems, altering evolutionary processes and threatening environmental stability (Khwansari, 1998:73).

Some of the negative consequences linked to biotechnology use include:

- Destruction of natural soil vegetation,
- Reduction or loss of nutritious plant diversity,
- Increase in carcinogenic substances in soil and water,
- Decline in fertility and lifespan of living organisms (Nadreeshhab, 1998:55).

Therefore, while acknowledging its positive achievements, biotechnology should be approached with caution, guided by thorough long-term studies and a strong emphasis on the safety of both current and future generations.

In this regard, **international environmental law** must assume its critical role in overseeing the global governance of biotechnology. It is positioned to play a **historical and regulatory role** in ensuring the responsible use of biotechnological innovations within the international community (Khansari, 1998:73).

The Conceptual Link Between Biotechnology and International Environmental Law

Human society has gradually come to understand the importance of establishing a balance between humanity and the natural environment. This shift in perspective has grown deeper and more widespread since the 1970s. Today, environmental awareness holds a much more prominent place in global discourse than it did in the past (Moussavi, 2012:19).

Since the 1970s, members of the international community have increasingly viewed adherence to environmental norms—not only as a way to protect nature but also as a necessity for their own social survival. There is now a widely acknowledged need to strike a sustainable balance between human activity and the environment (Pourhashemi & Arghand, 2013:26).

1. The Process of Conceptual Change in International Environmental Law

The current structure of international environmental law began to take shape in the mid-1970s, although its roots lie in broader legal developments from the second half of the 20th century. A key turning point in this evolution was the **1972 United Nations Conference on the Human Environment**, held in Stockholm, which marked the beginning of a new era in environmental governance.

The **Stockholm Declaration** was the first international instrument to explicitly acknowledge the relationship between human rights and environmental quality. It formally established the link between protecting the environment and safeguarding human well-being. The conference served as a catalyst for global and regional environmental initiatives (Massoudi, 2015:64). Another milestone was the **1992 United Nations Conference on Environment and Development (UNCED)**, held in **Rio de Janeiro**, Brazil. This landmark event brought together representatives from 176 countries, more than 50 intergovernmental organizations, and thousands of legal entities and non-governmental organizations.

The Rio Conference adopted three major **non-binding** instruments (Malkom Mohammadi Nouri, 1995:10):

- **The Rio Declaration on Environment and Development**
- **The Statement of Principles for the Sustainable Management of Forests** (also known as the 1992 Forest Principles)
- **Agenda 21**, a comprehensive action plan for sustainable development in the 21st century

In addition, the conference resulted in the adoption of two important international treaties:

- The **Convention on Biological Diversity (CBD)**
- The **United Nations Framework Convention on Climate Change (UNFCCC)**

A decade later, in **2002**, the **World Summit on Sustainable Development** was held in **Johannesburg** to review progress made since the Rio Conference. Although this summit did not result in the adoption of new treaties or principles, it focused on **poverty eradication** as a key component of sustainable development.

In **2012**, the international community convened again for the **Rio+20 Conference**, which aimed to assess progress in sustainable development over the previous two decades and to address emerging challenges. The outcome of this conference was summarized in the declaration **"The Future We Want."** One of the significant innovations of Rio+20 was the introduction of the **"green economy"** concept, which had not been clearly addressed in previous international documents. According to the **United Nations Environment Programme (UNEP)**, a green economy is one that enhances human well-being and social equity while significantly reducing environmental risks and ecological scarcities (Pourhashemi & Arghand, 2013:30–35).

Following the 1992 Rio Conference, there was a marked increase in **international environmental litigation**, reflecting the growing willingness of states to resolve environmental disputes on the international stage. It also signaled the growing recognition of environmental issues by **international courts**.

The **International Court of Justice (ICJ)** has addressed environmental concerns in several notable cases, including:

- *Nauru Phosphate Lands Case* (1992)
- *Advisory Opinion on the Legality of the Threat or Use of nuclear weapons* (1996)
- *Gabčíkovo-Nagymaros Project* (1997)
- *Pulp Mills on the River Uruguay* (2006)
- *Aerial Herbicide Spraying (Ecuador v. Colombia)* (2008)
- *Whaling in the Antarctic (Australia v. Japan)* (2010)
- *Construction of a Road in Costa Rica Along the San Juan River (Nicaragua v. Costa Rica)* (2011)

Today, **environmental protection** is no longer viewed as an isolated concern but as a fundamental aspect of all human activity. It has become deeply integrated into the legal, economic, and developmental priorities of the international community (Massoudi, 2015:91).

2. The Role of Biotechnology in the Development of International Environmental Law

In this section, we aim to demonstrate the role of biotechnology in the development of international environmental law by explaining how this emerging technology is connected to the sources, foundations, and legal principles that shape international environmental governance.

2.1 Biotechnology in the Context of International Environmental Law

Over the past two decades, environmental theorists and legal scholars have made substantial efforts to lay the groundwork for the development and implementation of legal principles and obligations relevant to environmental protection—particularly with respect to **state responsibilities** in addressing **transboundary environmental challenges**.

The negotiation and development of international environmental agreements—especially those aimed at **preventing environmentally harmful activities**—have provided a strong foundation for advancing the legal framework of international environmental law. These agreements help the international community better understand the essential relationship between the protection of the environment and the incorporation of environmental norms into binding and non-binding legal instruments. In this context, biotechnology plays a significant role in facilitating and accelerating environmental legal processes.

As we explore the link between **biotechnology** and the **rules and principles of international environmental law**, we focus on the role of biotechnology within the framework of **human rights and environmental obligations**, particularly through the lens of relevant legal instruments.

A) Biotechnology in the Context of the Human Rights Framework

1. The Convention on Biological Diversity (CBD)

The **Convention on Biological Diversity** (CBD) is one of the most important international legal instruments directly addressing biotechnology. Its objectives include:

- The conservation of biological diversity;
- The sustainable use of its components;
- The fair and equitable sharing of benefits arising from the use of genetic resources.

Article 19 of the Convention explicitly addresses **biotechnology** and the **sharing of its benefits**. Specifically:

- **Paragraph 1** calls on member states, particularly developed countries, to take appropriate legislative and

administrative measures to create an enabling environment that promotes the **participation of developing countries** in **biotechnology research** and related activities.

- **Paragraph 2** emphasizes the importance of providing developing countries with **equitable access** to the benefits resulting from the utilization of biological resources. It encourages developed nations to share the outcomes of biotechnological advancements based on **mutually agreed terms** (Molaei et al., 2014:3).

Through these provisions, the CBD highlights the importance of biotechnology in achieving its goals. It recognizes the **positive contributions** of biotechnology in areas such as:

- Transformations in the agricultural sector;
- Conservation and protection of plant and forest species;
- Prevention of environmental crises such as soil erosion and biological pollution;
- Development of sustainable, supportive frameworks for the use of nature, with a simultaneous emphasis on **preservation and long-term ecological survival**.

The CBD clearly calls for **increased participation of states**—especially developing nations—in biotechnology research and policymaking. This, in turn, requires governments to take **legislative and executive action** to ensure fair access, responsible use, and the protection of biodiversity.

2. The Cartagena Protocol on Biosafety

Biosafety refers to the set of standards and procedures designed to minimize the potential risks associated with biotechnology, ensuring its safe and effective application (Mortazawi, 2013:14). **Biodiversity**, organized across multiple levels—genes, individuals, species, communities, and ecosystems—requires careful consideration when any changes are made at these levels. Even minor modifications can have widespread and lasting consequences.

To support the **sustainability and conservation of genetic resources** and ensure overall **biological security**, a number of measures have been emphasized, including:

- Coordination among biodiversity-related activities across ecosystems,
- Management of economically significant species while preserving genetic diversity,
- Promotion of public awareness, education, and scientific knowledge,
- Evaluation and oversight of biosafety-related technologies and projects (Mohammedifazil, 2000:23).

In light of these concerns, the **member states of the Convention on Biological Diversity (CBD)** adopted the **Cartagena Protocol on Biosafety**—an additional protocol to the CBD—on **January 29, 2000**.

The **Cartagena Protocol** emphasizes the importance of **precautionary measures**, building upon **Principle 15 of the Rio Declaration on Environment and Development**, which asserts: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

In line with this principle, the **primary goal** of the Cartagena Protocol is to establish an international framework for the **safe transfer, handling, and use of living modified organisms (LMOs)** that may have adverse effects on biodiversity, while also considering potential risks to human health (Molaei et al., 2014:4). Given the potential of biotechnology to cause irreversible damage—such as biodiversity loss and harm to plant and animal species—when applied irresponsibly or outside legal frameworks, the need for **preventive decision-making** is critical.

The **precautionary approach** emphasized by the Protocol not only requires the development of relevant legislation but also the establishment of **specialized institutions** to supervise and regulate biotechnology research and products. This includes:

- Monitoring genetically modified organisms (GMOs),
- Overseeing biosafety research,
- Enforcing legal compliance in biotechnology development and use.

In sum, the Cartagena Protocol represents a cornerstone of the international biosafety regime, encouraging countries to **act responsibly and collaboratively** in mitigating the potential environmental and health risks posed by biotechnology.

3. The Lugano Convention

The **Council of Europe's Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment**, also known as the **Lugano Convention**, was adopted in **Lugano on 21 June 1993**.

According to **Article 2(3)** of the Convention, **biotechnology** is defined as follows:

"Biotechnology means genetically modified organisms in which the modification does not occur naturally through reproduction or natural recombination."

Unlike other international conventions that limit their scope to **negligent environmental damage**, the **Lugano Convention** covers **all environmentally hazardous activities**, regardless of whether the damage was caused intentionally or negligently. This broader scope strengthens the international legal framework in holding actors accountable for **any** form of environmental harm.

The **objective** of the Lugano Convention is to ensure **adequate compensation** for damages resulting from dangerous environmental activities. In addition to liability and compensation mechanisms, it also incorporates **preventive and restorative measures** to minimize environmental degradation and restore affected areas (Taqizada Ansari & Faiqirad, 2010:25).

The inclusion of biotechnology within the scope of this convention illustrates the growing concern within international law over the **risks associated with genetically modified organisms (GMOs)** and their potential to cause unintended, long-term environmental harm.

B) Biotechnology and Soft Rights

In the development of international environmental law, **soft law instruments**—such as declarations, guidelines, and action plans—have played a crucial role in shaping norms, influencing behavior, and providing frameworks for cooperation. Although **non-binding**,

these documents often serve as the basis for future treaties and domestic policy, especially in emerging fields like **biotechnology**.

1. The Rio Declaration

The **Rio Declaration on Environment and Development** grants importing countries the right to regulate or reject the import and distribution of **biotechnology products**, taking into account their **economic and social interests**. This provision was designed to help control the **potentially adverse effects** of genetically modified organisms (GMOs), particularly in cases where genetically modified foods are **replacing traditional food sources** without sufficient scientific evaluation.

The lack of scientific consensus in some cases has raised concerns about the **risks of biodiversity loss**, especially within **indigenous communities**, where traditional agricultural practices and native species are vulnerable to displacement.

The primary **objective** of the Rio Declaration is to ensure **adequate protection** in the **transfer, conservation, and use of living modified organisms (LMOs)** that may negatively impact **biodiversity conservation** and the **sustainable use of natural resources** (Pourhashemi & Arghand, 2013:36).

2. Agenda 21 (Guideline 21)

Agenda 21 is a comprehensive **non-binding action plan** for global cooperation on **sustainable development**, adopted at the **1992 Earth Summit in Rio de Janeiro**. It addresses several critical issues, including:

- Ecosystem degradation
- Poverty
- Public health
- Population growth

Biotechnology plays a vital role in advancing the objectives of Agenda 21 by supporting the **sustainable use of renewable resources** and promoting the **responsible utilization of natural resources**. Notably, **Chapter 16, Section 2** of Agenda 21 underscores the importance of **transferring biotechnology** to **developing countries**. It calls for the development of **institutional infrastructure** and **human resources** to enable those countries to harness biotechnology for sustainable development (Shehbaz, 2010:14).

The **international transfer of technology** has historically played a pivotal role in the economic and industrial advancement of various countries. For example, experiences in **East Asia** and **Latin America** demonstrate that **access to advanced technologies**—paired with education and skill development—can significantly boost productivity and economic resilience (Hajihosseini, 1998:11).

3. The Johannesburg World Summit

The **World Summit on Sustainable Development**, held in **Johannesburg in 2002**, reaffirmed the commitments made during the **Rio Earth Summit** and emphasized the need for a **global approach** to addressing pressing challenges such as:

- Poverty alleviation
- Improving the living conditions of vulnerable populations
- Preventing environmental degradation and destruction

The **final report** of the Johannesburg Summit referred to poverty eradication and environmental protection as **"overarching global challenges"** (Report of the World Summit on Sustainable Development, Johannesburg: 2002).

Reinforcing the goals of earlier environmental declarations, the summit recognized the transformative potential of **new technologies**, including **biotechnology**, in shaping national and subnational development. It emphasized the ability of these technologies to influence areas such as:

- Food security
- Healthcare and medicine
- Environmental protection

The summit highlighted biotechnology's potential to help **eradicate disease and hunger**, especially in **developing nations**, where technological solutions can address fundamental challenges related to health, agriculture, and sustainability.

C) Biotechnology in the Mirror of International Environmental Law Principles

1. The Principle of Permanent Sovereignty of States over Natural Resources

The **principle of sovereignty** is one of the **fundamental pillars of international environmental law**. It is firmly embedded in the **domestic laws** of many nations and has deep roots in **customary international law** (Pourhashemi & Arghand, 2013:71).

This principle is reflected in major international environmental instruments, including:

- **Principle 21 of the 1972 Stockholm Declaration**
- **Principle 2 of the 1992 Rio Declaration**

These documents affirm that:

"In the pursuit of environmental preservation and protection, states are permitted to generate income and implement development policies, provided that these actions are consistent with the United Nations Charter and internationally accepted legal principles. Such policies must also be equitable and regulated to avoid causing harm or damage to other countries or areas beyond national jurisdiction." (Pourhashemi & Arghand, 2013:72)

Accordingly, states have the **sovereign right** to exercise **exclusive authority** over their **natural resources**. However, the exercise of this right must not lead to **harm to other states** or to **shared ecosystems beyond national borders**.

Sovereignty implies that each state has the freedom to **formulate policies** and enact **laws** regarding the **management and exploitation of natural and environmental resources** within its territory (Moussavi, 2012:25).

The **Convention on Biological Diversity (CBD)** reinforces this notion by affirming the **sovereign rights of states** over their **genetic and biological resources**. It also recognizes the importance of setting standards to regulate:

- The **registration of biotechnological inventions**
- The **protection of intellectual property rights**
- **Access to and transfer of technology**

The CBD, as a treaty negotiated between **developed countries** (often possessing advanced technology but limited biodiversity) and **developing countries** (rich in biodiversity but often lacking technological infrastructure), sparked significant debate (Sadiqi, 2005:94).

For example, some developing countries—such as **India**—argued that developed nations:

- Expected them to **conserve natural resources** (such as forests),
- While **ignoring the economic value** of these resources,
- And **failing to provide fair compensation or technological support**.

These countries advocated for more equitable arrangements that would include:

- **Technology transfer** to improve scientific and financial capacities,
- The **right to impose conditions** on access to biological resources,
- Fair **benefit-sharing mechanisms** based on the **economic value of biodiversity**.

Conversely, many **developed countries** and **multinational corporations** opposed restrictive access frameworks. They preferred **fewer legal limitations** on access to genetic and biological resources, arguing that excessive regulation could hinder scientific innovation and commercial development (Sadeghi, 2005:94). Although the **CBD (Article 15, paragraph 4)** allows states to **define the conditions** under which access to genetic resources may be granted ("on mutually agreed terms"), the **lack of binding international regulations** in this area remains a significant gap.

Furthermore, the CBD's **provisions on equitable benefit-sharing** are largely **general and ambiguous**, which disproportionately impacts **developing countries**, as they often lack the legal and financial infrastructure to enforce their rights. The **United States** has **not signed or ratified the CBD**, citing concerns that the treaty's provisions on **intellectual property rights** may **restrict the operations of its biotechnology industry**.

In contrast, many **developing countries** view the CBD as a tool to **enhance national control** over their biological resources and to push for a **fairer global framework** governing the **use of biodiversity and biotechnology** (Sadiqi, 2005:94).

2. Principles: Prevention and Precaution

According to the **precautionary principle**, states have a duty to prevent actions that may cause environmental degradation or pollution. Where necessary, they must take appropriate precautionary measures (Deberi et al., 2009:218).

This principle has been either directly or indirectly incorporated into several international instruments, including:

- The **1972 Stockholm Declaration**,
- The **World Environment Day Programme (1978)**,
- The **1982 Rio Declaration**, and
- **Principle 15 of the 1992 Rio Declaration**, which formally emphasized precautionary action.

While the **positive outcomes of biotechnology** are considerable, these benefits should not result in overlooking the **potential risks** associated with neglecting **biosafety principles** (Massoudi, 2015:125).

The relationship between **biotechnology and the precautionary principle** can be examined at two levels:

- On the one hand, **precautionary use of biotechnology** can **prevent ecological crises**, such as soil erosion, biological pollution, and the degradation of plant and forest species caused by environmental stressors.
- On the other hand, **misuse of biotechnology**, particularly in countries lacking regulatory infrastructure, **can result in unpredictable and harmful consequences**.

Some studies suggest that **genetically modified organisms (GMOs)** can have **adverse effects** on **human health** and the **environment**. Links have been observed between **herbicide use** and **birth defects**, **cancer**, and **other severe environmental impacts** (Khansari, 1998:72).

Therefore, the **international community**, recognizing the intrinsic value of **nature and natural resources** for the **collective future of humanity**, should engage in **greater international cooperation**. Through global conferences and the **drafting of appropriate legal instruments**, states can work together to prevent potential environmental harms arising from biotechnology.

As such, the **role of states in preventing environmentally harmful activities** becomes increasingly important. It is not only a legal obligation but a moral imperative to ensure the **long-term safety and sustainability** of the planet (Khaddadadi, 2014:10).

3. The Principle of Sustainable Development

The **United Nations Conference on Environment and Development (1992)** officially recognized **sustainable development** as an **effective model** for improving **human quality of life**.

Sustainable development, as reflected in various international legal instruments, encompasses **environmental, economic, and social** dimensions (Massoudi, 2015:130). These include:

- **Access to safe and adequate food**
- **Clean drinking water**
- **Unpolluted air**

These are considered fundamental **human rights**, and **governments bear the primary responsibility** to ensure their provision.

Without sustainable development, goals such as **poverty alleviation**, **food security**, and **public health** cannot be achieved. **Poverty, hunger, and malnutrition** are not only causes of many diseases but also sources of major social and cultural crises in human societies.

Sustainable development involves using resources, directing investments, and adopting technologies in ways that meet the **needs of the present** without compromising the **ability of future generations** to meet their own. It addresses five main areas:

1. Balancing **conservation and development**
2. Meeting **basic human needs**
3. Promoting **social justice**

4. Preserving **cultural diversity**
5. Ensuring **ecological integrity** (Nakhda & Zain al-Abedini, 2013:1)

Biotechnology, as a powerful and modern tool, can significantly contribute to achieving these goals.

Traditional plant breeding, while valuable, faces many challenges, such as:

- The **long duration** and **high cost** of producing improved varieties
- **Technical limitations** in transferring desired traits between species
- Difficulties in **removing undesirable traits** through conventional breeding

Biotechnology has revolutionized this process by enabling:

- The rapid development of **new plant varieties** using **recombinant DNA technology**
- Application of **cellular and molecular biology** techniques to overcome conventional barriers

This has made it possible to obtain high-yield, resilient crops **more quickly and cost-effectively**, paving the way for **greater food security** and **economic growth**.

Today, a key marker of national development is the **extent of technological integration**—especially biotechnology—in agricultural, medical, and industrial sectors. **Access to advanced technology** is essential for **modern development**.

The **true value of investment** lies in the ability to **transform knowledge into wealth**—through the development of new technologies, technological products, and competitive global markets. Biotechnology clearly holds immense potential in these areas.

Thus, by upholding core international environmental law principles—such as the **precautionary principle**, the **principle of cooperation**, and the **polluter pays principle**—we can significantly **reduce the harmful impacts** of biotechnology and ensure it is used to advance **sustainable development** for current and future generations (Molaei et al., 2014:2).

4. Biotechnology and the Codification and Development of International Environmental Law

A diverse array of factors influences the evolution of international environmental law, including science and technology, geopolitics, non-state actors, judicial systems, and human rights frameworks. This section focuses on **science and technology**, particularly biotechnology, and examines how it has shaped both **binding and non-binding international instruments**.

How Biotechnology Propels Legal Development

1. **Science Driving Legal Formulation**
   Advancements in biotechnology often prompt the formalization of legal principles and obligations. Environmental law evolves in response to these scientific developments, highlighting their indispensable role in shaping norms.
2. **Rise of Soft Law**
   A defining feature of international environmental law is its origin in **soft law instruments**—such as declarations and action plans, which are not legally enforceable yet serve as foundational guidelines. Over time, these have paved the way toward more binding treaties and regulations.
3. **Influence of Non-State Actors**
   NGOs, scientific associations, and civil society have played vital roles in steering environmental discourse and legal outcomes. Their participation in landmark conferences (e.g., Stockholm, Rio) and their observatory status in treaties underscore their power to shape norms and mold **public opinion**. This influence has been particularly visible in raising awareness and support for the deployment of biotechnology—balancing innovation with ecological foresight.
4. **Shaping Norms from Soft to Hard**
   Biotechnology has been a core factor in codifying and transitioning soft norms into enforceable international law. Its growing role in environmental protection has shifted the discourse toward **integrated policies** and away from fragmented, issue-specific regulations.

Practical Applications and Innovations

Biotechnology's strategic applications include:

- **Preserving biodiversity** and enhancing plant resilience.
- **Preventing soil erosion** through improved pasture species.
- **Reducing chemical fertilizer and pesticide use** via biofertilizers.
- **Reclaiming arid, saline, or degraded lands** by developing genetically modified crops suited to challenging environments.

Investment in:

- Research,
- Skilled personnel,
- Laboratory infrastructure,

…is essential for harnessing biotechnology's environmental potential. Equally important is the **inclusion of diverse stakeholders**—from scientists to local communities—in risk awareness and safety protocols.

Legal and Normative Responses

1. **Concerns Prompt Regulation**
   Recognizing biotechnology's promise and threats, states participating in the Rio Earth Summit and the CBD advocated for a clear legal framework—leading to the **Cartagena Protocol**, which embodies precaution-based governance.
2. **Liability Mechanisms**
   At the regional level, the Council of Europe initiated frameworks like the **Lugano Convention** to ensure accountability for ecological harms stemming from biotechnology.
3. **Precaution in Practice**
   The adoption of precautionary norms may influence scientific research but encourages reflection on the long-

term consequences of premature or unfettered biotechnology deployment.

4. **Balancing Innovation with Conservation** Biotechnology must prioritize sustainability and not turn ecosystems into "genetic laboratories" for profit. Upholding principles of prevention, precaution, and "polluter pays" ensures responsible progress.
5. **Legal Frameworks and Due Diligence** Many countries advocate for:
    - Environmental impact assessments,
    - Prior informed consent before introducing GMOs,
    - National liability and compensation regimes.
6. **Expanding Litigation and Enforcement** Since Rio in 1992, a growing body of environmental laws and international judicial attention has strengthened legal enforcement capacity, so the global community can better regulate biotechnological risks.

Challenges and Future Outlook

1. **Cooperation Hurdles** Technological access remains uneven—tainted by economic and commercial interests that hinder equitable collaboration between developed and developing nations.
2. **Exploitative Trade Dynamics** Rising GMO imports in developing nations often occur under commercial pressure, paired with inadequate awareness of safe usage. States must enact biosafety regulations and prohibit unchecked distribution.
3. **Need for a Unified Governance Framework** International instruments should harmonize technological progress with ecological integrity—ensuring that principles guide both policy and practice, with legal certainty for environmental protection.
4. **Biotechnology as a Regulatory Lever** Its centrality in global economic and ecological systems makes biotechnology a key axis for shaping future environmental norms.

Conclusion

With the expiration of the Millennium Development Goals, the **Rio+20 Summit** emphasized renewed frameworks for sustainable development, foregrounding concerns such as resource depletion, deforestation, and freshwater scarcity. As we move toward the **Sustainable Development Goals (SDGs)**, tools like biotechnology must advance development **without sacrificing environmental health**.

- **Biotechnology enables** the codification of environmental norms—from soft declarations to robust legal frameworks.
- Its pivotal role in human and economic progress makes it a determinant of national and global development capacity.
- Strategic governance—through international, regional, and domestic law—ensures biotechnology serves society and the planet sustainably.

By integrating environmental law principles—such as precaution, social justice, and accountability—into biotech regulation, we can secure a future were innovation and nature flourish together.

General Conclusion

With the expiration of the Millennium Development Goals (MDGs) in 2015, the Rio+20 Summit underscored the urgent need to design a new framework for global development beyond 2015. Key challenges such as the depletion of natural resources and environmental degradation—including deforestation, drought, land degradation, freshwater scarcity, and biodiversity loss—were prominently highlighted. Now, as the Sustainable Development Goals (SDGs) shape the global agenda, it is crucial to focus on effective mechanisms and tools that can guide progress toward these objectives. However, it is imperative that such tools and mechanisms do not inadvertently contribute to environmental destruction or pollution.

Biotechnology, by intervening in and harnessing natural processes and organisms, offers a vital framework for codifying principles and transforming soft norms into binding rules, thereby facilitating the advancement of international environmental law. It stands as a fundamental axis of scientific, social, and economic development worldwide and serves as a key indicator of a country's development level.

The wide-ranging applications of biotechnology demonstrate its potential to improve human life and environmental health. For example, the use of microorganisms to detoxify pollutants and the conservation and sustainable utilization of genetic resources are notable contributions in this regard. Yet, this technology also carries risks that could lead to environmental harm and pollution if not carefully managed. Over recent decades, the environmental implications of biotechnology have garnered significant global attention and have been extensively debated in international forums, especially since the landmark 1992 United Nations Conference on Environment and Development. This event laid a strong foundation for the evolution of international environmental law.

Achieving the goals of international environmental law today relies on mechanisms designed to prevent degradation and pollution. Unfortunately, some of these mechanisms lack robust enforcement guarantees, leading to occasional neglect. Nonetheless, international environmental law is evolving, moving toward formalized commitments and organized avenues for redress in cases of violations. Biotechnology's profound influence in various sectors, particularly environmental protection, has helped shape global awareness and concern for the environment. The world community increasingly recognizes that the era of a one-sided relationship between humans and nature has ended; the preservation of life depends on the harmonious interaction between humanity and the natural world.

Finally, clarifying the many uncertainties surrounding the use of biotechnologies—an area with few precedents in international law—will depend on the collective actions and vision of states, international organizations, and non-state actors. Continued cooperation in this field will be crucial for shaping a sustainable and equitable future.

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