EIGHT

Eyes on the Planet

Toward Zero Deforestation

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Disappearing Forests in the Tropics

Forests are an irreplaceable resource for all living creatures, especially human beings. In a figure dubbed "the Wedding Cake," the Stockholm Resilience Centre mapped the SDGs into three tiers—a foundational biosphere supporting a set of societal goals that, in turn, support economic goals. In this structure, they placed sustainable forest management within targets for SDG 15 "Life on Land" as part of the biosphere.[1]

Viewed in this way, forest management is a foundational goal that directly contributes to many other goals. Forests serve as a huge carbon stock. They absorb carbon dioxide from the air and release oxygen as trees grow. In addition, forests contribute to water purification and watershed conservation (see, for example, "The Sea Is Longing for the Forest" by Shigeatsu Hatakeyama,[2] an account of the forest management efforts that have been made in Japan to protect water quality for sustainable oyster farming). Furthermore, sustainable use of forest resources can provide incomes to marginal communities, helping achieve SDG 1 "No Poverty," improve land use practices that help achieve SDG 2 "Zero

The authors are grateful to Dr. Homi Kharas and Dr. Izumi Ohno for suggesting the topic treated in this paper. We also thank Dr. Takeo Tadono and Dr. Izumi Nagatani from JAXA for reprocessing the JJ-FAST dataset for us. This work has been supported by JICA-JAXA Forest Early Warning System in the Tropics (JJ-FAST).

1. Stockholm Resilience Centre.
2. Hatakeyama.

Hunger," and generate timber, fuels, and non-timber forest products (NTFPs) that contribute to SDG 12 "Responsible Consumption and Production."

However, forests are decreasing. According to the FAO, the world's forest coverage area has been reduced from 4.24 billion hectares in 1990 to 4.06 billion hectares in 2020.[3] This has resulted in 4 Gt (gigatons) of carbon being released into the atmosphere. The problem is particularly severe in tropical forests of the Amazon, Congo Basin, and Southeast Asia. These forests, which comprise only 7 percent of the planet's land area but are home to 50 to 80 percent of Earth's living creatures, are also crucial in terms of biodiversity.

The drivers of the deforestation of tropical forests vary by country and region but include agriculture (small-scale for subsistence and large-scale for commerce), fuelwood harvesting, urban development, and mining excavation. Relatively large deforestation is caused by cattle farming in Brazil and palm oil tree plantations in Indonesia. Meanwhile, in the least developed countries, population growth is driving an increase in small-scale land-use changes for food production and deforestation and forest degradation for fuelwood harvesting. There are no simple solutions to these problems, reportedly aggravated by COVID-19.[4]

Taking into account the importance of forests for climate mitigation and other SDGs, the international community has already, at the 2014 United Nations Climate Summit, committed to reduce the global rate of deforestation in natural forests by at least half by 2020 and to zero by 2030 (Goal 1 of the New York Declaration on Forests (NYDF)). However, the most recent progress report for NYDF points out, "Rather than halving since 2014—a 2020 target in NYDF Goal 1—the rate of natural forest loss has increased. Ending natural forest loss by 2030 will require a rapid paradigm shift by the global community toward valuing forests for their essential benefits and prioritizing their protection."[5]

Achieving the goal of zero reduction in natural forests by 2030 requires support for the private sector to eliminate deforestation from agricultural production, strengthening of forest governance, and community empowerment. There has been some success in providing alternative livelihoods to reduce forest usage by the poor. For example, a "Participatory Forest Management Project in Belete--Gera Regional Forest Priority Area," Phase 1 (2003–06), Phase 2 (2006–12), funded by the Japan International Cooperation Agency (JICA), showed how a coffee certification program had a large impact on forest protection and decreased the probability of deforestation by 1.7 percentage points.[6]

Such efforts are, however, limited. Even if the concerned countries and

3. FAO.
4. Brancalion and others.
5. NYDF Assessment Partners.
6. Takahashi and Todo.

international development agencies promote alternatives, it remains a huge challenge to secure sustainable forest management in places without clearly defined land use planning, monitoring, and enforcement.

The breakthrough we envisage in the next five years is to establish land use plans, including forest areas, in all developing countries, to monitor forest usage, and to control illegal deforestation through improved remote sensing and data processing and through a radical expansion of advocacy to change corporate incentives toward forest preservation rather than destruction.

When forest monitoring is done through surveys by forest officers, it takes massive time and effort, and information is processed too slowly for effective prosecution of illegal deforestation. Thus, the use of remote sensing by Earth observation satellites becomes very important for the efficient and effective monitoring of vast forests. When this data is seamlessly linked with field data, there can be effective forest management. One example of this operating in practice is a JICA Technical Cooperation Project, "Sustainable Natural Resources Management Project" (2015–21), conducted in Vietnam. In this project, the forest data collected by the forest patrolling team, which included locals on the ground, was input into tablets by forest rangers and then used for forest management. By inputting information in a digital format rather than through paper surveys, the team transferred the data directly into the forest management system and combined with remote sensing data. In addition, already processed remote sensing data was viewed and ground-truthed in the field using tablets.

This example shows the potential for remote sensing technologies to operate national forest monitoring systems and also to lead to improvements in forest governance, investment for social responsibility, and finally zero deforestation. In this chapter, the history of forest monitoring using satellite "Machine Eyes"—"Optical Eyes" and "Radar Eyes"—to improve the ability of forest authorities to enforce laws against illegal deforestation is briefly explained. Then we argue that a breakthrough to achieve zero deforestation is possible by combining improved "Machine Eyes" and "Smart Eyes" with "Functional Eyes" and "Eyes of People."

The History of "Machine Eyes": Achievement of Forest Monitoring by Remote Sensing

Forest Monitoring by "Optical Eyes": Visual Grasp of the Earth

Dating back to the 1970s, optical satellite images—"Optical Eyes"—have been used to monitor the vast forests of Brazil, home to 60 percent of the world's largest tropical forest, the Amazon. Deforestation monitoring started in 1974, using Landsat, and has been conducted using the Amazon Deforestation Satellite Monitoring Project (PRODES) program since 1988. Visual interpretation work has been performed by semiautomatic processes such as supervised classification with gradual improvement of analysis methods as the processing power of computers has advanced. At the global level, a number of systems are used to monitor annual forest change, including WRI's Global Forest Watch, which uses the GLAD (Global Land and Discovery) forest change algorithm developed by the University of Maryland,[7] and the national forest monitoring system (NFMS) developed by various countries, for sustainable forest management. Many of these systems are supported by a recent cloud computing system that has made it possible to process huge amounts of data. A country-level NFMS helps to understand entire forest areas and is also utilized in REDD+ activity and other applications. For example, the Brazilian government was granted US$96.5 million from the Green Climate Fund's (GCF) REDD+[8] results-based payments in 2019,[9] thanks to the efforts of the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) to monitor forests based on field activities and satellite information and to furnish this data to the federal and state police under the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm).

To take effective action, deforestation must be monitored at all times to discover changes as soon as possible. An early warning system (EWS) for deforestation is needed. In Brazil, the authorities have used the Terra and Aqua satellite's MODIS sensor to monitor deforestation of 25 hectares or larger as the target for illegal deforestation control on a nearly daily basis since 2004. Following a change in satellite data sources from MODIS to Landsat and China-Brasil Earth Resources Satellite (CBERS) in 2015, the detection of deforestation is possible in areas as small as 6.25 hectares as the control target.

The Brazilian process for controlling illegal deforestation works from detection to enforcement and starts with the National Institute for Space Research (INPE) using multiple optical satellites under the Near Real-Time Deforestation Detection System (DETER) program to detect deforestation. From INPE, suspected deforestation data (illegality is unknown, at this stage) are sent to IBAMA, the regulatory agency for illegal deforestation. IBAMA and its branches then compare DETER and other EWS data against the satellite imagery, a database of legal land use, and other matters. When deforestation appears to be highly illegal, the authorities move in to enforce the law, sometimes with the support of the federal police and other institutions. In Brazil, satellite images are also used as documentary evidence for prosecuting illegal deforestation operators by determining exactly when and over what area the deforestation occurred.

7. Hansen and others.

8. REDD+ is an abbreviation for Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests, and Enhancement of Forest Carbon Stocks in Developing Countries.

9. Green Climate Fund.

Other EWS programs at the international level include NASA's Forest Monitoring for Action (FORMA), GLAD Forest Alert, and Global Forest Watch. These are built upon Landsat data and are updated roughly every sixteen days, according to the regression cycle of the satellite. At the national level, only a few countries have their own EWS, because it requires a huge amount of data and rapid analysis rather than the usual forest monitoring system. Besides Brazil, Peru operates an EWS system that custom-tailors the GLAD Forest Alert system to its own vegetation, the Alerta Temprana in the Geo Bosques system.[10]

In tropical forests, however, the ground is often difficult to observe. The skies are covered in dense clouds during the rainy season and can be covered by altocumulus or cirrocumulus clouds even during the dry season. The annual average cloud coverage, calculated by Wilson and Jetz using MODIS data,[11] shows that areas with tropical forests, such as the Amazon Basin, Congo Basin, and Southeast Asia, have especially high cloud coverage rates, which may pose difficulties in using optical satellites such as Landsat for EWS. In Brazil, as the use of optical satellites in monitoring illegal deforestation is common knowledge, illegal deforestation operators have adapted by cutting down forests during the rainy season, using cloud cover to avoid optical satellite detection.

If "Optical Eyes" were to shoot images more frequently, there would be a better chance of obtaining pictures during gaps in the clouds. To date, almost daily observations have been possible by utilizing MODIS data from the wide-range Terra and Aqua satellites, although resolution suffers, given the widened range for each observation. This explains why, in the early stages, Brazil's DETER program was able to detect areas of deforestation only 25 hectares or greater. Thus, there is an unavoidable trade-off between observational frequency and resolution. The narrative, however, is changing, thanks to significant technological innovations such as using constellations of commercial microsatellites to capture multiple images each day. Even so, using this technology for early detection of deforestation over large areas is still not practical. Given the narrow observation range per image, monitoring the Amazon, for example, would require data processing on a massive scale, and no images could be taken if cloud cover lasts all day.

Forest Monitoring by "Radar Eyes": Observing the Earth through Clouds

Another means of monitoring is using radar satellites. "Radar Eyes" can solve the weaknesses of optical satellites. Radar satellites are equipped with synthetic aperture radar (SAR) in which the satellite emits radio waves, which are then

10. Ministry of Environment of Peru.
11. Wilson and Jetz.

captured by sensors as they are reflected back from the surface, in contrast to "Optical Eyes," which capture the reflection of sunlight. Being emitted from satellites, as long as the bandwidth used is long enough to pass through clouds, ground activities can be analyzed by captured radio wave reflections even when it is cloudy or at night. Starting with JERS-1 in 1992, and later ALOS and ALOS-2, Japan has operated radar satellites using the L-band, a longer bandwidth that has advantages in sensing vegetation. Since the early 2000s, the monitoring of tropical forests has used data from such radar satellites. These include the Brazil-based ALOS project conducted from 2009 to 2012,[12] which produced significant results. These projects detected more than a thousand examples of deforestation, including 150 prosecuted illegal deforestation cases from 2010 to 2011. Over a hundred investigation reports of illegal deforestation have been created for evidence in court procedures. As a result, the extent of deforestation in 2014 was 500,000 hectares, about 80 percent less than the 2004 level.

Given these results, the use of radar satellite technology has been considered in other countries with tropical forests, although challenges remain. Unlike with the satellite imagery from optical satellites, few people are adept at working with radar satellite images, making data interpretation difficult. As a workaround, rather than training image interpreters in each country, the detection of deforestation has been automated, and information-receiving countries are simply provided with the results that they then superimpose on their own diverse data sets to verify and prosecute illegal operations. To achieve this outcome, the JICA--JAXA Forest Early Warning System in the Tropics (JJ-FAST),[13] an EWS using ALOS-2 data, was developed as a tool to allow foreign forest officers to allocate more of their strength to field efforts in sustainable forest management. JJ-FAST has been operational since November 2016.

JJ-FAST detects forest changes of two hectares or more from data collected approximately once every forty-five days by ALOS-2 for seventy-seven target countries. It publishes this polygonal data on the JJ-FAST website. Since going operational, JJ-FAST has detected 284,823 cases of deforestation as of March 2020. JJ-FAST has been utilized in technical cooperation projects in South America and Africa, including Brazil, Peru, Cameroon, Mozambique, and the DRC.

The use of JJ-FAST has improved the detection of deforestation of areas greater than two hectares. GLAD Alerts can see smaller individual areas of deforestation, and so captures more than JJ-FAST in the aggregate, but for the larger areas, it missed significant episodes. In 2019, JJ-FAST detected 11,175 km^2 of deforestation, while GLAD Alerts detected 4,093 km^2 of deforestation of areas

12. The project name is "Utilization of ALOS Images to Support Protection of the Brazilian Amazon Forest and Combat against Illegal Deforestation."

13. Japan International Cooperation Agency.

greater than two hectares in the Brazilian Legal Amazon. Particularly during the rainy season from January to April and from October to December, when cloud coverage is extremely high—87.71 ± 2.99 percent, based on data from Wilson and Jetz (2016)—and optical satellite imagery rarely permits ground observation, the area of deforestation detected by optical satellites decreases. However, once the dry season from May to September started, which means the cloud coverage is reduced (53.58 ± 8.31 percent, based on the data cited above), the deforestation area detected by GLAD Alerts has increased (table 8-1). This is because deforestation that could not be detected during the rainy season was detected along with actually increased deforestation in the dry season. It should be noted that the correctness of deforestation data is not taken into account in both JJ-FAST and GLAD Alerts data.

The JJ-FAST data are updated every forty-five days. In previous exchanges with the countries utilizing JJ-FAST, it became apparent that some countries considered this refresh rate to be insufficient. However, given how rarely the clouds clear away enough for optical satellites to observe the ground during the rainy season, even every forty-five days is thought to be a significant improvement.

The Brazilian Amazon is vast, and the monthly cloud cover rate varies from region to region. Figure 8-1 shows the area of deforestation detected by JJ-FAST and GLAD Alerts every other month for January–December 2019 in an area separated by one degree, for each cloud cover rate. It is clear that the GLAD Alerts detect more areas (with up to 75 percent cloud cover) than JJ-FAST. However, beyond 75 percent cloud cover, the area detected by JJ-FAST increases and deforestation detection by radar satellites becomes dominant.

Thus, "Radar Eyes" allow detecting deforestation earlier than "Optical Eyes" in the rainy season when the cloud cover rate is high and dense clouds cover the tropical rainforest. This advantage of radar satellites may help forest authorities to enforce laws more effectively. In fact, deforestation detection by JJ-FAST significantly reduces deforestation, according to a statistical analysis using satellite data of 2019 in the Brazilian Amazon. There is a statistically significant negative relationship between the deforestation area detected by radar satellites (reported by JJ-FAST) in the previous months and the area of deforestation detected by optical satellites (reported by GLAD) in the current month, conditional on the area detected by optical satellites in the previous months. This means that the detection of deforestation by radar satellites (JJ-FAST) will significantly reduce further deforestation in the future, suggesting the effectiveness of radar satellites as an enforcement device for forest protection.[14]

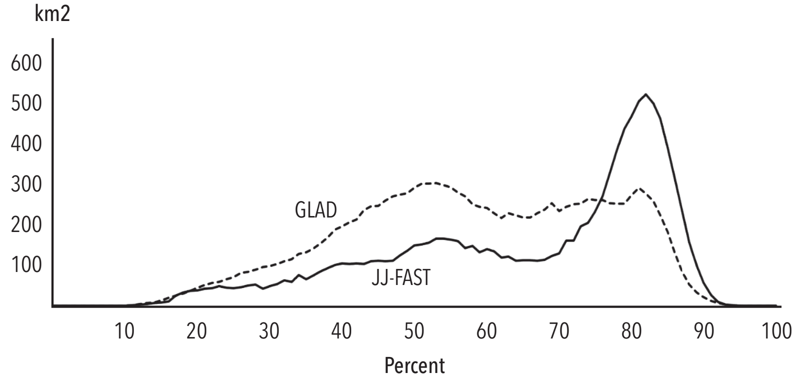
14. The details of the statistical analysis on the benefit of radar satellite (JJ-FAST) appear in Yamada and others (2021), www.brookings.edu/blog/future-development/2021/07/02/protecting-forests-are-early-warning-systems-effective/.

Table 8-1. Monthly Deforestation Areas Estimated by JJ-FAST, GLAD, and GLAD (Over 2 Hectares) Models in 2019 in the Brazilian Legal Amazon (Square Kilometers)

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
JJ-FAST	422.91	705.13	771.52	482.18	371.35	762.50	1081.69	1226.95	1696.24	1184.03	1632.84	837.57
GLAD	245.26	240.91	531.05	820.90	943.72	1726.21	2176.11	2779.88	2101.55	1624.78	587.44	72.79
GLAD (over 2 ha)	91.78	71.57	190.22	305.52	420.54	626.02	586.16	693.88	519.00	428.53	141.76	17.60

Source: Authors' calculations

Figure 8-1. Deforestation Areas Detected by JJ-FAST and GLAD Alerts per 1-Degree Mesh by Each Cloud Cover Ratio, Divided into Every 1 Percent in the Brazilian Legal Amazon Area, in January to December 2019



Source: Authors' calculations

However, to date, JJ-FAST cannot detect deforestation of less than two hectares due to the resolution of the ALOS-2 data used. To detect deforestation at a truly early stage, it is necessary to detect smaller areas of deforestation even during the rainy season, and to do so, it is necessary to use SAR data with higher spatial resolution. With ALOS-2, it is also possible to produce images with high spatial resolution, such as three-meter square or six-meter square. However, the observation width is 50 km, compared to 350 km at fifty-meter square spatial resolution, which is used for JJ-FAST. Thus, in the same way as for optical satellites, there is an unavoidable trade-off between observational frequency and resolution.

Alternative approaches, such as a constellation of small radar satellites, are under consideration. However, they require more power than optical satellites for radio wave radiation, so they need large solar panels and batteries. In addition, due to the characteristics of capturing the intensity of reflections from the ground, advanced attitude control is also required to handle time-series data. Therefore, large satellites still have an advantage. On the other hand, improvements in technology have led to the development of large satellites that can perform highly spatially resolved observations over a wide observation range, and it is expected that new large radar satellites will be launched and utilized in the future.

Future Breakthrough with "Eyes": Issues to Be Solved for Sustainable Forest Management

Improvement of "Functional Eyes": Enhancement of Forest Governances Utilizing "Machine Eyes"

As efforts to improve deforestation detection accuracy press forward, illegal deforestation operators are adapting. According to Richards and others, before PRODES started, illegal deforestation happened regardless of area size. However, once the program started, deforestation of small plots under 6.25 hectares increased while it decreased in larger plots.[15] Moreover, according to IBAMA, before the ALOS-based project, illegal deforestation was rampant during the rainy season, due to cloud coverage, because monitoring relied solely on optical satellites. Once the ALOS project started and it became widely known that radar satellites were detecting deforestation even during the rainy season, this became an effective deterrent. However, deforestation operators started switching to spraying herbicidal defoliants from aircraft flying under the clouds, to kill the forest, and then setting fire to it. In this method, the deforestation goes unnoticed for some time. Radar satellites still see standing trees, so they judge that the forest remains intact. Optical satellites could observe the changes of the "health status" of trees, because the leaves turn yellow or brown after being sprayed, but cannot capture images when the cloud cover is heavy. There is no end in sight to the cat-and-mouse games between deforestation detection technology and illegal deforestation methods, so prospects for achieving zero deforestation based on these techniques remain poor.

There is an additional complication. No matter how developed the technology, and no matter how accurately deforestation is detected, it will all be meaningless without an anti-deforestation policy and framework in place, and without the forest officers to enforce that policy. To enhance forest governance and administrative capacity, "Functional Eyes," utilizing "Machine Eyes," are required. Even Brazil, which has succeeded in decreasing deforestation of the Amazon Basin, cannot officially distinguish whether each deforestation case is legal or illegal without investigation of each situation.[16] Therefore, enforcement of deforestation control policy and information needs to be highly integrated. With the launch of JJ-FAST, JICA and JAXA also launched the Forest Governance Initiative (FGI) to use satellite technology to improve forest governance. FGI minimizes the effort allotted to satellite data analysis, looking to free up human resources to focus on improving and enforcing policy and, as a result, enabling the execution of better

15. Richards and others.
16. Hummel.

forest policy through technology. In fact, in technical cooperation projects in Peru,[17] the FGI has already assisted in introducing JJ-FAST and other data, and in establishing roundtable meetings for local deforestation crackdowns. Furthermore, FGI goes beyond just policies to properly regulate illegal deforestation to include the larger question of how to prevent deforestation due to the conversion of land—that is, how to develop without deforestation.

Encouragement of the "Eyes of People": Involvement of Global Stakeholders in the Forest Sector

The utilization of satellite data for forest monitoring has the potential to increase the transparency of forest policy.[18] In November 2020, Norway launched a program to publish high-resolution optical satellite images free of charge to monitor deforestation. Its users include investors, journalists, scientists, indigenous peoples, and NGOs. The minister of climate and environment of Norway, Sveinung Rotevatn, said that "indigenous people themselves can use this satellite imagery as their own surveillance tool in the struggle against infringement of rights with large companies; global supermarket companies can use it as a confirmation tool for unilateral proof that it is an environmentally friendly product (especially primary products such as soybeans and palm oil) from suppliers."[19]

In Brazil, the Central Bank and the Ministry of Environment have teamed up with private soy and beef producers to suspend access to agricultural credit for those farms and ranches located in the counties with the highest deforestation rates. This has succeeded in drastically reducing deforestation in some counties.[20] Brazilian soybean giants, such as Bunge,[21] Cargill,[22] and ADM,[23] have committed to zero deforestation to align with PPCDAm to promote sustainable agriculture and responsible supply chains. By doing so, they reduce the risk of having their reputations in international markets tarnished by anti-deforestation advocacy campaigns.[24] The public and private sectors are working together to achieve zero deforestation.[25]

In Indonesia, a paper giant, Asia Pulp & Paper (APP), has also committed

17. The project name is "Project on Capacity Development for Forest Conservation and REDD+ Mechanisms" (2016–21).

18. Fuller.

19. KSAT.

20. Nepstad and others.

21. Bunge.

22. Cargill.

23. ADM.

24. Seymour and Harris.

25. Lambin and others.

to zero deforestation. However, NGOs, using open-source satellite data, have accused them of acting in violation of that commitment.[26] This is an example of how transparency, enabled by the “Eyes of People” watching through the “Machine Eyes,” can reveal corporate malpractice. With NGOs, investors, bankers, and general citizens all able to use satellite data as a source of objective information on deforestation, the reputational risks to any corporate malpractice have risen dramatically.[27]

Building “Smart Eyes”: Predicting Deforestation for Precautions against Illegal Activities

Until now, deforestation detection by “Machine Eyes” has only been able to reveal events after the fact. Even the speedy JJ-FAST takes several days to process satellite images. By the time of detection, the forest has already been cut. This is the weakness of traditional remote sensing. Looking forward, what is needed is to predict deforestation before it happens. Similar to predicting traffic conditions and crimes, it should be possible to predict deforestation locations in advance by identifying the latent drivers of deforestation, analyzing the historical drivers of deforestation patterns. Based on these predictions, the deforestation control agencies could efficiently conduct monitoring and patrolling before the forests are cut down. There is a possibility then to build a “Smart Eyes” deforestation prediction system.

To set up a system to effectively predict illegal deforestation, which can be used both in dry and in rainy seasons, the following is required: (1) radar satellite data to detect deforestation even during the rainy season, as well as the resulting calculation data of the exact deforestation locations; (2) socioeconomic data to determine the latent drivers of deforestation; and (3) massive computing power to apply AI (deep learning) to satellite imagery in quantity. Rather than reiterating these actions for each country, as JJ-FAST has done to date, predictive models should be based on an international platform that can process data by supercomputers (or cloud computing resources) using information from all over the world. The results could also be distributed all over the world.

With Landsat being in use since the 1970s, a huge amount of data has been accumulated from optical satellites, and this is enough to perform AI image recognition. Meanwhile, radar satellites, especially with L-band radar such as JERS-1 and ALOS, have also accumulated a great amount of satellite imagery. Moreover, a new L-band satellite, the successor of ALOS-2, is also planned. All

26. Jong.
27. Galaz and others.

this data promises to usher in a new era of more accurate deforestation detection and the start of deforestation prediction through AI analysis.

If such a system is developed, preventive measures against illegal deforestation can be effectively implemented, and the deterrent effect of being under constant surveillance can be realized. Moreover, based on the predicted information on deforestation, appropriate sustainable forest resource management programs such as the introduction of alternative livelihoods and incentive schemes for development without deforestation can be implemented.

Potential of "Eyes on the Planet": Priority Actions toward the Achievement of Zero Deforestation

Throughout human history, we have been developing the capacity of "Eyes." The desire to understand the world visually seems almost instinctive. The ancient Greek philosophers tried logic to describe the cosmos beyond the reach of the naked eye. In the fifteenth century, the invention of the telescope expanded our naked eye capacity and opened the door to the remarkable development of astronomy and natural science. The evolution of "Eyes" is part of the ongoing process by which people consolidate and expand their image of the world.

Satellites are leading the way in the innovation of "Eyes." The first satellite was the USSR's Sputnik 1, launched in 1957. Today, just over sixty years later, thousands of satellites orbit the earth with more to come. These "Machine Eyes" have expanded our naked-eye capacity dramatically in a short time and, as we have discussed in this chapter, the satellite data and information on the earth has become indispensable for sustainable forest management. In the near future, by combining AI technology with satellite data, we should be able to witness the development of "Smart Eyes" able to predict deforestation to tackle this illegal activity with far more accuracy.

In our everyday life, we receive original data through the naked eye. Then we process and analyze the raw sensory data in our brain to make decisions. In the same way, we can use "Machine Eyes" and "Smart Eyes" to mechanically absorb input data while "Functional Eyes" and the "Eyes of People" help us make decisions using this data.

We are on the cusp of a breakthrough for forest conservation as a result of improvements to each "Eye on the Planet." "Machine Eyes" and "Smart Eyes" are providing ever more accurate and timely data. "Functional Eyes" and the "Eyes of People," are fueling the actions needed to deter illegal activity and encourage corporations, local communities, financiers, and other stakeholders to commit to zero deforestation and to be held accountable for these pledges. We could say that the road to zero deforestation is being built in the sky.

References

ADM. "ADM Commitment to No-Deforestation Policy Implementation H1 2018 Soy Progress Report," https://assets.adm.com/Sustainability/2018-Soy-Progress-Report.pdf.

Brancalion, Pedro H. S., Eben N. Broadbent, Sergio De-Miguel, Adrián Cardil, Marcos R. Rosa, Catherine T. Almeida, Danilo R. A. Almeida, and others. "Emerging Threats Linking Tropical Deforestation and the COVID-19 Pandemic." *Perspectives in Ecology and Conservation*, September 30, 2020. doi:10.1016/j.pecon.2020.09.006.

Bunge. "Bunge Announces Significant Progress against Deforestation Goals in South America," www.bunge.com/news/bunge-announces-significant-progress-against-deforestation-goals-south-america.

Cargill. "Cargill in the Amazon and Our Commitment to Ending Deforestation in Our Supply Chains," www.cargill.com/story/cargill-in-the-amazon-and-our-commitment-to-ending-deforestation.

Fuller, Douglas O. "Tropical Forest Monitoring and Remote Sensing: A New Era of Transparency in Forest Governance?" *Singapore Journal of Tropical Geography*, v. 27 (2006): 15–29. doi:10.1111/j.1467-9493.2006.00237.x.

FAO, "Global Forest Resources Assessment 2020: Main Report." Rome, 2020.

Galaz, Victor, Beatrice Crona, Alice Dauriach, Bert Scholtens, and Will Steffen. "Finance and the Earth System—Exploring the Links between Financial Actors and Non-Linear Changes in the Climate System." *Global Environmental Change*, v. 53 (November 1, 2018): 296–302. doi:10.1016/J.GLOENVCHA.2018.09.008.

Green Climate Fund. "FP100-REDD-PLUS Results-Based Payments for Results Achieved by Brazil in the Amazon Biome in 2014 and 2015," www.greenclimate.fund/project/fp100.

Hatakeyama, Shigeatsu, *The Sea Is Longing for the Forest* (in Japanese). Kyoto: Hokuto-syuppan, 1994.

Hansen, Matthew C., Alexander Krylov, Alexandra Tyukavina, Peter V. Potapov, Svetlana Turubanova, Bryan Zutta, Suspense Ifo, Belinda Margono, Fred Stolle, and Rebecca Moore. "Humid Tropical Forest Disturbance Alerts Using Landsat Data." *Environmental Research Letters*, v. 11, no. 3 (March 2, 2016). doi:10.1088/1748-9326/11/3/034008.

Hummel, Antônio Carlos. "Deforestation in the Amazon: What Is Illegal and What Is Not?" *Elementa: Science of the Anthropocene*, v. 4 (December 8, 2016). doi:10.12952/journal.elementa.000141.

IPCC, "Climate Change 2014: Synthesis Report," Geneva, 2014.

Japan International Cooperation Agency. "JICA-JAXA Forest Early Warning System in the Tropics," www.eorc.jaxa.jp/jjfast/.

Jong, Hans Nicholas. Mongabay, "Report Finds APP and APRIL Violating Zero-Deforestation Policies with Wood Purchases from Djarum Group Concessions in East Kalimantan," https://news.mongabay.com/2018/08/report-finds-app-and-april-violating-zero-deforestation-policies-with-wood-purchases-from-djarum-group-concessions-in-east-kalimantan/.

KSAT. "KSAT, with Partners Planet, and Airbus Awarded First-Ever Global Contract to Combat Deforestation," www.ksat.no/news/news-archive/2020/ksat-awarded-global-contract-combat-deforestation/.

Lambin, Eric F., Holly K. Gibbs, Robert Heilmayr, Kimberly M. Carlson, Leonardo C. Fleck, Rachael D. Garrett, Yann Le Polain De Waroux, and others. "The Role of Supply-Chain Initiatives in Reducing Deforestation." *Nature Climate Change*, v. 8, no. 2 (February 1, 2018): 109–16. doi:10.1038/s41558-017-0061-1.

Ministry of Environment of Peru. Geo Bosques, geobosques.minam.gob.pe/geobosque/view/index.php.

Nepstad, Daniel, David McGrath, Claudia Stickler, Ane Alencar, Andrea Azevedo, Briana Swette, Tathiana Bezerra, and others. "Slowing Amazon Deforestation through Public Policy and Interventions in Beef and Soy Supply Chains." *Science*, v. 344, no. 6188 (June 6, 2014): 1118–23. doi:10.1126/science.1248525.

NYDF Assessment Partners. "Balancing Forests and Development: Addressing Infrastructure and Extractive," https://forestdeclaration.org/.

Richards, Peter, Eugenio Arima, Leah VanWey, Avery Cohn, and Nishan Bhattarai. "Are Brazil's Deforesters Avoiding Detection?" *Conservation Letters*, v. 10, no. 4 (July 7, 2017): 470–76. doi:10.1111/conl.12310.

Seymour, Frances, and Nancy L. Harris. "Reducing Tropical Deforestation." *Science*, v. 365, no. 6455 (August 23, 2019): 756–57. doi:10.1126/science.aax8546.

Stockholm Resilience Centre. "How Food Connects All the SDGs," June 14, 2016, www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html.

Takahashi, Ryo, and Yasuyuki Todo. "The Impact of a Shade Coffee Certification Program on Forest Conservation: A Case Study from a Wild Coffee Forest in Ethiopia." *Journal of Environmental Management*, v. 130 (November 30, 2013): 48–54. doi:10.1016/j.jenvman.2013.08.025.

Wilson, Adam M., and Walter Jetz, "Remotely Sensed High-Resolution Global Cloud Dynamics for Predicting Ecosystem and Biodiversity Distributions." *PLOS Biology*, v. 14, no. 3 (March 31, 2016). doi:10.1371/journal.pbio.1002415.

Yamada, Eiji, Hiroaki Okonogi, and Takahiro Morita. "Protecting Forests: Are Early Warning Systems Effective?" *Future Development* (blog), Brookings Institution, July 2, 2021.