INTERNET PROVISION PROGRAM IN INDIGENOUS COMMUNITIES IN THE COLOMBIAN ANDEAN MOUNTAINS

By: Environmental Women ORG

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SUMMARY

The **Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains** is a community-driven initiative led by *Environmental Women ORG*, aiming to deploy resilient and culturally-adapted community networks to bridge the digital divide in four highly vulnerable indigenous communities: Narakajmanta, Wiwa, Kankuamos, and Kogui. These communities, located across 14,000 hectares of the Sierra Nevada de Santa Marta, are facing the dual crisis of accelerated climate change and chronic disconnection from digital infrastructure. The absence of internet connectivity in these territories has magnified the consequences of climate-related hazards, notably the increase in vector-borne diseases such as dengue, chikungunya, and malaria, as well as the inability to report and respond to forest fires fueled by prolonged drought and rising temperatures. In the last five years, disease outbreaks in these communities have increased by 60%, while the number of uncontrolled forest fire events has tripled, threatening sacred territories and critical biodiversity corridors.

In response, our program will design, install, and maintain decentralized wireless mesh networks powered by renewable energy systems, following the principles and phases outlined in the *Community Network DIY Toolkit*: **assessment, planning, deployment, and sustainability**. A total of eight solar-powered connectivity nodes will be established in strategic sites, each with a minimum range of 5 kilometers and connected to a central backbone point leveraging long-range Wi-Fi or satellite backhaul. These nodes will ensure broadband access for approximately 5,200 indigenous people, 70% of whom are women, girls and LGTBI caregivers playing vital roles in health, food, and environmental stewardship. The technical infrastructure will include solar panels with battery systems, ruggedized routers, towers or masts built with local materials, and open-source firmware with embedded caching systems to reduce bandwidth costs and ensure offline access to key public health and climate response resources.

The program is rooted in community ownership and technical empowerment. Thirty-five indigenous women and youth will be trained as *Community Network Stewards*, in charge of maintenance, first-level support, and climate-health data collection using digital tools. Locally developed dashboards and early warning content will be integrated into the network, including vector-disease surveillance maps, open-access fire detection systems, and downloadable public health protocols in native languages. The system will also incorporate a feedback loop between indigenous knowledge and scientific data, ensuring mutual reinforcement for disaster preparedness and cultural preservation. We anticipate a 70% increase in early alerts reaching caregivers and a 50% reduction in fire-reporting times by the second year of implementation.

This program is more than a connectivity project: it is a transformative, ecofeminist model for digital climate justice, driven by indigenous women and grounded in resilience. By embedding connectivity within a broader vision of environmental management, gender equity, and self-determination, the initiative will offer a scalable blueprint for other disconnected and climate-vulnerable indigenous territories in Latin America and beyond.

INTRODUCTION

The digital divide is no longer a question of mere access—it is a structural determinant of vulnerability in the face of accelerating climate change. In the Colombian Andean mountains, particularly in the Sierra Nevada de Santa Marta, this divide is acutely experienced by the indigenous communities of Narakajmanta, Wiwa, Kankuamos, and Kogui. These communities, composed of approximately 5,200 people and spread across 14,000 hectares of high-biodiversity ancestral territories, remain largely disconnected from digital infrastructure. This condition exacerbates their exposure to climate-related hazards and severely limits their ability to access life-saving information, coordinate emergency responses, and participate in digital economies and policy spaces.

According to the Colombian Ministry of ICT (MinTIC), as of 2023, only 18% of rural indigenous households in the Caribbean region report regular internet access, and fewer than 8% have access to broadband with speeds above 5 Mbps. In the Sierra Nevada, satellite-based coverage is sparse, unstable, and unaffordable, with monthly costs exceeding USD $80 for minimal data packages—an amount that represents more than 45% of the average monthly income in these communities. This systemic disconnectivity coexists with a climate crisis that is rapidly intensifying. Between 2020 and 2023, regional temperature anomalies averaged +1.6°C above historical norms, and the frequency of climate-sensitive vector-borne diseases such as dengue, chikungunya, and malaria increased by over 60%, as reported by the Colombian National Health Institute. Simultaneously, forest fire events—often triggered by prolonged droughts and illegal land-use practices—have tripled, destroying over 1,200 hectares of forest in the last three years and threatening both biodiversity and sacred indigenous territories.

Environmental Women ORG, a women-led ecofeminist organization established in 2009 and headquartered in the Sierra Nevada region, has documented firsthand the disproportionate impacts of this dual crisis on women, girls, and LGTBI caregivers. These groups are primarily responsible for water collection, food preparation, health care, and environmental stewardship. In the absence of internet access, they are unable to receive epidemiological alerts, health protocols, or early warnings for climate-related emergencies. Nor can they document and report threats such as illegal logging or forest fires in real time. The result is a silent erosion of their autonomy, well-being, and territorial sovereignty.

The introduction of locally-governed, resilient, and sustainable community networks—following the methodology established in the Internet Society's *Community Network DIY Toolkit*—offers a pathway to transform this reality. Rather than depending on top-down telecommunication models, this approach emphasizes collective ownership, open-source technologies, and horizontal training processes to build long-term digital resilience. By embedding the network within a climate and health adaptation framework, the proposed program will ensure that connectivity is not an end in itself, but a means to strengthen community-based early warning systems, public health responses, and indigenous-led climate monitoring.

The Internet Provision Program will thus serve as a foundational intervention to integrate decentralized wireless infrastructure with gender-responsive capacity building and culturally-adapted digital content. This will enable real-time access to fire detection platforms, vector surveillance data, health information repositories, and

community reporting channels—delivered in local languages and formats. It will also provide opportunities for youth and women to take leadership in maintaining digital systems, collecting environmental data, and using digital tools to safeguard their territories. In doing so, the program aligns with the principles of environmental justice, digital inclusion, and indigenous self-determination, offering a scalable model for climate-resilient digital infrastructure in marginalized contexts.

PROBLEM STATEMENT

In the context of the accelerating climate crisis and unequal digital development in Colombia, the indigenous communities of Narakajmanta, Wiwa, Kankuamos, and Kogui, located in the Sierra Nevada de Santa Marta, face a compounded threat. These communities—comprising an estimated 5,200 individuals across 14,000 hectares of ancestral land—remain digitally disconnected in a region where climate-related health emergencies and environmental hazards are increasing in frequency, severity, and unpredictability. The lack of internet infrastructure has rendered these populations acutely vulnerable to climate-induced vector-borne diseases and forest fires, while also excluding them from national and regional platforms for risk communication, public health response, and climate adaptation.

Over the past five years, the region has seen a significant rise in disease incidence directly linked to climate variability. According to data from Colombia's National Institute of Health, cases of dengue, chikungunya, and malaria in the Caribbean mountain departments increased by 63% between 2019 and 2023. The elevation of average regional temperatures by +1.6°C, paired with more erratic rainfall patterns, has expanded the breeding grounds and altitudinal range of disease vectors such as *Aedes aegypti* and *Anopheles* mosquitoes. In communities without access to reliable internet, there is no means of receiving early epidemiological alerts, participating in public health campaigns, or accessing updated prevention and treatment protocols. Traditional knowledge, while invaluable, is not sufficient to respond to these novel and rapidly evolving threats. In consequence, the majority of cases are detected late, and women and girls—who are typically primary caregivers—suffer the greatest burden of disease, both physically and economically.

Simultaneously, the Sierra Nevada has experienced an alarming increase in forest fires. Between 2020 and 2023, the Colombian Environmental Information System (SIAC) reported over 1,200 hectares of forest lost in the region, with at least 37 major fire events affecting indigenous reserves. These fires are fueled by prolonged droughts, rising temperatures, and land-use pressures, yet the affected communities lack the technological means to detect, document, or report outbreaks in real time. Without connectivity, early warning systems based on satellite imagery or environmental sensors remain out of reach. The result is delayed response times, loss of biodiversity—including endemic and sacred species—and irreparable damage to spiritual and cultural sites.

The lack of internet connectivity not only exacerbates the impacts of climate change—it also limits the ability of these communities to assert their rights. Exclusion from digital communication impedes participation in environmental governance, data sovereignty initiatives, and disaster risk reduction

platforms. It reinforces structural inequalities, marginalizes indigenous knowledge in public policy, and perpetuates dependence on external actors for access to information, aid, and visibility. In many cases, women and LGTBI community members, already facing social and gendered discrimination, are disproportionately excluded from existing emergency responses due to their inability to communicate needs, report incidents, or access support networks.

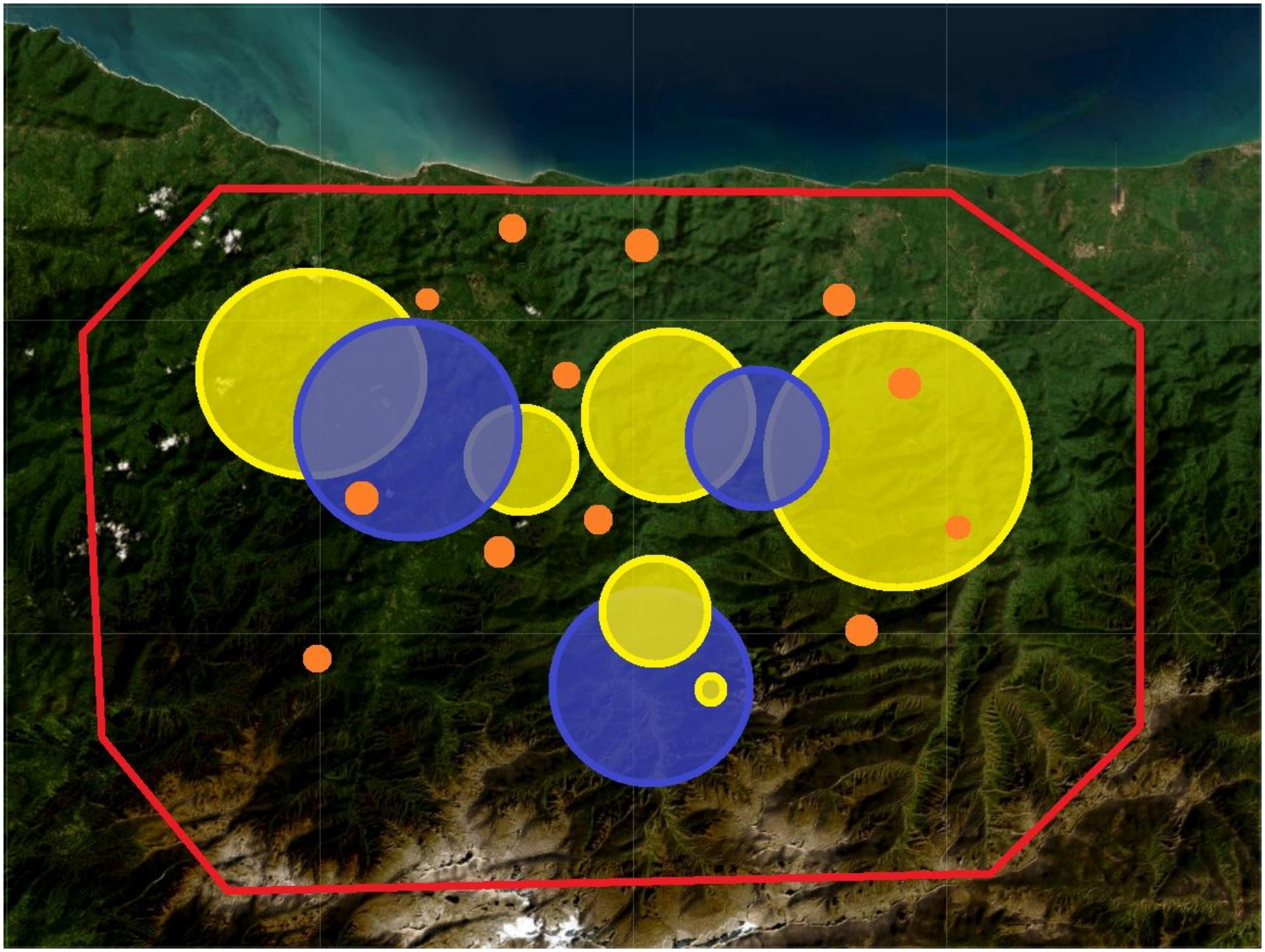
Ultimately, the absence of a reliable, community-owned internet infrastructure creates a systemic barrier to resilience. It hinders the operationalization of locally-led climate adaptation, delays critical health interventions, and prevents the development of hybrid knowledge systems that combine indigenous environmental stewardship with digital tools. Addressing this problem is urgent—not only to reduce loss of life and environmental degradation, but to empower communities to become active agents in climate governance and digital inclusion.

PARTICIPATION OF INDIGENOUS COMMUNITIES

The active and sustained participation of the Narakajmanta, Wiwa, Kankuamos, and Kogui indigenous communities was fundamental to the design, implementation, monitoring, and governance of the *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains*. Rooted in principles of intercultural dialogue, free, prior and informed consent (FPIC), and collective sovereignty, the participatory framework combined qualitative and quantitative methodologies—including focus groups, technical roundtables, and semi-structured interviews—to ensure that community knowledge, priorities, and values shaped each stage of the intervention. In the initial phase, **16 focus groups** were conducted (four per community), involving a total of **192 participants**, with an emphasis on inclusive representation—**67% of participants were women, 15% were LGTBI persons**, and **30% were youth under 25 years old**. These dialogues were facilitated in Spanish and local indigenous languages (including Damana and Iku), with support from trained intercultural mediators. The focus groups explored themes such as digital access needs, climate vulnerabilities, gendered burdens related to water and health care, and cultural perspectives on technology. The process revealed critical insights, such as the disproportionate time (up to 3.5 hours daily) women spend walking to access water sources, and the community's perception of rising vector-borne diseases as a spiritual and environmental imbalance exacerbated by deforestation and climate variability.

These findings informed the structure and thematic focus of the **Technical Community Roundtable (Mesa Técnica Indígena de Conectividad y Clima)**, a governance mechanism composed of **16 appointed representatives** (four per community, with at least two women per group). The Mesa Técnica met monthly throughout the implementation phase (a total of 10 formal sessions), functioning as a decision-making body and liaison with the Environmental Women ORG technical team. It reviewed and approved the network infrastructure layout, the location of the solar-powered connectivity hubs, and the prioritization of digital content (e.g., epidemiological alerts, fire prevention protocols, maternal health information). It also ratified the selection process for the 35 Community Network Stewards, integrating community authority validation with transparent technical criteria.

PROJECT MAP



INTERNET PROVISION PROGRAM IN INDIGENOUS COMMUNITIES IN THE COLOMBIAN ANDEAN MOUNTAINS

	Project area
	Non-connected Rural Zones
	NARAKAJMANTA indigenous settlements
	Focuses of sexual violence and exploitation of girls and women, water collectors

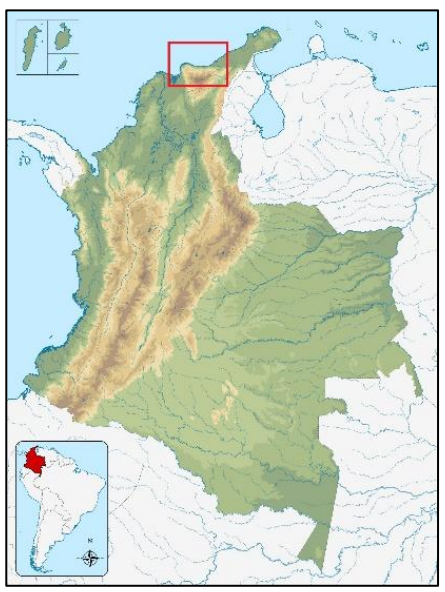
SCALE

1cm = 1,000 meter

SOURCES

- Environmental Women ORG
- Google Maps

- **Country:** COLOMBIA
- **Departments:** Magdalena
- **Cities:** Santa Marta
- 9,800 hectares of Narakajmanta indigenous territory
- **Geographic coordinates:** From 11°12'14.9"N 73°55'05.3"W and 11°11'40.9"N 73°26'37.7"W; to 10°57'41.6"N 73°54'13.9"W and 11°01'29.7"N 73°29'35.7"W



In parallel, **62 semi-structured interviews** were carried out with elders, traditional healers, youth leaders, midwives, and local educators. The interviews provided nuanced understandings of the relationship between connectivity, traditional knowledge, and climate resilience. For example, elders emphasized the risk of losing oral memory due to the absence of platforms for intergenerational knowledge transfer, while youth expressed frustration over their inability to access environmental education or participate in national climate dialogues. The interviews also revealed a consensus on the need for a culturally-appropriate governance framework for technology use—grounded in principles such as collective benefit, reciprocity (*minga digital*), and respect for sacred sites.

Based on these participatory exercises, a **Community Digital Participation Protocol** was drafted and endorsed by the tribal councils, establishing roles, responsibilities, data protection norms, and mechanisms for community oversight. This protocol defined access levels to the intranet and internet platforms, established procedures for the use of fire and disease alert systems, and delineated the duties of the Community Network Stewards and the Community Connectivity Hubs.

Furthermore, two **territorial planning workshops** were conducted with a combined participation of **80 leaders and traditional authorities**, where participatory mapping tools and low-tech GPS devices were used to identify priority zones for connectivity, areas at high climate risk, and sacred territories requiring monitoring or digital documentation. These maps were digitized and integrated into the network planning process through GIS layers.

Overall, community participation was not treated as a one-off consultation, but as a continuous, iterative process of co-creation, negotiation, and empowerment. This sustained engagement ensured the cultural legitimacy, technical relevance, and social ownership of the program, strengthening indigenous autonomy in the management of digital and environmental resources. The integration of indigenous epistemologies into network design, health communication, and fire response systems is a direct result of this participatory architecture, which now serves as a replicable model for climate-digital collaboration in other indigenous territories.

MATERIALS AND METHODS

The implementation of the *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* will follow a phased methodology grounded in the **Community Network DIY Toolkit** developed by the Internet Society. The program's technical and social deployment strategy is designed to address the compounded risks of climate change and digital exclusion across four indigenous communities—Narakajmanta, Wiwa, Kankuamos, and Kogui—distributed over 14,000 hectares in the Sierra Nevada de Santa Marta. Each methodological phase integrates community-led planning, sustainable energy infrastructure, open-source technology, and climate-health integration to ensure long-term operability, scalability, and resilience.

The first phase involves a **comprehensive digital and climate vulnerability assessment** across all target communities. Using participatory mapping methods, 40 local leaders (75% women and LGTBI members) will collect data on current connectivity levels, key climate hazards (e.g., flood-prone zones, fire-prone corridors), and health risk areas based on incidence of dengue, malaria, and chikungunya. These assessments will inform the **Network Design Blueprint**, which will identify optimal locations for wireless nodes based on line-of-sight analysis, terrain elevation, population density, and climate sensitivity. Geospatial tools such as QGIS and Google Earth Pro will be used in combination with field-validated GPS coordinates.

The **core technological infrastructure** includes the installation of **eight solar-powered wireless mesh network nodes** covering a cumulative area of 14,000 hectares. Each node will consist of:

- A 150W photovoltaic panel system with a 100Ah deep-cycle battery and charge controller.
- One or two long-range wireless routers (Ubiquiti LiteBeam AC Gen2 or Mikrotik LHG) with 5 GHz directional antennas.
- A local micro-server or Raspberry Pi 4 with RACHEL or Internet-in-a-Box firmware to store offline content (health protocols, fire response plans, educational material).
- Mast towers between 6–10 meters, constructed with galvanized tubing and anchored with concrete and steel cable systems, adapted for high wind resistance.
- Power surge protectors and waterproof casings for all outdoor equipment (IP65/IP66 rated).

The network's **backhaul** will be established using a hybrid approach combining **long-range point-to-point Wi-Fi** and **VSAT (Very Small Aperture Terminal)** satellite internet solutions, depending on terrain access. The estimated bandwidth per node will range between 10–30 Mbps, sufficient for multi-user access, VoIP reporting, and environmental data synchronization. Each community will be equipped with a central **Community Connectivity Hub**, outfitted with 5–10 tablets, a projector, basic UPS (Uninterruptible Power Supply) systems, and public access terminals, managed by trained local stewards.

Training and capacity-building form a critical component. A cohort of **35 Community Network Stewards** (with a minimum of 60% women and LGTBI participation) will receive 60 hours of hands-on instruction in wireless network management, solar maintenance, data protection, and climate-health digital tools. Training will be based on the *Wireless Networking in the Developing World* curriculum and adapted with climate-specific modules developed with support from health and fire prevention agencies.

In parallel, the project will establish an **early warning digital content system**, integrating open-access datasets (NASA FIRMS for fire detection, IDEAM for meteorology, INS for disease surveillance) with automated SMS/email alerts and visual dashboards. These will be made accessible through locally-hosted captive portals

and voice alert systems in indigenous languages, allowing low-literacy users to receive critical updates in real time.

All software used will be open source, including OpenWRT for routers, Node-RED for automation, and KoBoToolbox for community data collection. Evaluation of network performance and social impact will occur quarterly, using key metrics such as latency, uptime (target 95%), number of users, fire alerts transmitted, and health protocol downloads.

By embedding technical infrastructure in a participatory and culturally-adapted framework, this methodology ensures that the community network is not only operational but sustainable and transformative, enabling real-time climate-health responses and fostering digital sovereignty in territories long excluded from the information society.

TECHNICAL STRATEGY

The technical strategy of the *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* is designed to establish a resilient, low-cost, and community-owned wireless communication infrastructure capable of supporting real-time climate and health responses. Rooted in the principles of technological sovereignty and adapted to the geographic and climatic challenges of the Sierra Nevada de Santa Marta, the strategy integrates decentralized network architecture, renewable energy systems, local capacity-building, and open-source tools to provide sustainable broadband connectivity to four indigenous communities: Narakajmanta, Wiwa, Kankuamos, and Kogui.

At the core of the technical approach is the **deployment of a wireless mesh network (WMN)** composed of eight interconnected nodes distributed across 14,000 hectares of mountainous and forested terrain. This topology ensures redundancy, load balancing, and scalability, which are essential for ensuring uninterrupted service in areas prone to extreme weather events. Each node will be built using **dual-band routers** (preferably Ubiquiti Rocket M5 and Mikrotik hAP ac³) flashed with **OpenWRT firmware**, enabling full customization, bandwidth control, and captive portal functionality. The firmware will also include mesh routing protocols such as **BATMAN-adv** or **OLSRv2**, which allow dynamic rerouting in case of node failure or temporary signal loss due to environmental interference.

To overcome the **lack of commercial electrical infrastructure**, each node will be powered by an **autonomous solar energy system** tailored to the energy load profile of rural telecommunication equipment. The design includes 150W to 300W monocrystalline solar panels, 100Ah LiFePO4 batteries, MPPT solar charge controllers, and a protective enclosure to ensure operation during prolonged cloudy periods. The energy system will provide at least 24 hours of autonomy, with a target uptime of **95%**, crucial for maintaining early warning services and digital health access.

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Backhaul connectivity will follow a hybrid model: in two of the most accessible communities, **line-of-sight long-range Wi-Fi links** (5 GHz PTP links) will be established using directional antennas (range: 10–15 km) to reach existing fiber nodes in nearby towns. In the remaining two, **VSAT (Very Small Aperture Terminal)** satellite technology will be employed. Partnering with satellite providers offering Ka-band coverage in Colombia, such as HughesNet or SES, will guarantee a minimum symmetric bandwidth of **10 Mbps per site**, enough to support concurrent users, synchronize cloud data, and facilitate real-time alerting. Bandwidth consumption will be optimized using **caching servers** (Raspberry Pi with RACHEL or Internet-in-a-Box) at each node to store static content locally (e.g., health guides, fire prevention manuals, educational materials), thereby reducing reliance on external data flow.

To facilitate interaction with climate and health platforms, the network will be integrated with **open APIs** and web scraping tools to retrieve data from:

- **NASA FIRMS** (Fire Information for Resource Management System) for forest fire alerts via MODIS and VIIRS satellite.
- **IDEAM Colombia** for rainfall, temperature, and weather warnings.
- **INS (Instituto Nacional de Salud)** for vector-borne disease epidemiological bulletins. These data will be converted into **multilingual, community-friendly alerts**, disseminated via text-to-speech systems on local servers and visual dashboards accessible through mobile devices or public terminals.

A **Network Operations Center (NOC)** will be created at Environmental Women ORG headquarters, using low-cost monitoring tools such as Zabbix and LibreNMS. This NOC will oversee uptime, bandwidth usage, hardware health, and intranet traffic. An alert system based on Node-RED will be configured to notify local technicians and stewards via SMS or Telegram in case of service degradation, battery failures, or suspected tampering.

The strategy also includes **end-user access infrastructure** through Community Connectivity Hubs equipped with rugged tablets, LED screens, routers with VLAN segmentation, and solar-powered UPS systems to ensure availability even during grid failures. Security and privacy will be enhanced using DNS filtering, HTTPS enforcement, and training in digital hygiene.

Overall, the technical strategy combines robustness, modularity, and community participation to transform connectivity into a platform for climate resilience and public health empowerment. By ensuring technical self-sufficiency and interoperability with global environmental systems, this strategy aligns with the principles of the Internet Society and strengthens indigenous autonomy in the digital age.

Educational Strategy

The educational strategy of the *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* is designed as a structured, inclusive, and gender-sensitive capacity-building process that aims to foster long-term technological autonomy, climate resilience, and public health awareness across the

Narakajmanta, Wiwa, Kankuamos, and Kogui indigenous communities. It combines non-formal education models with technical training, digital literacy, environmental pedagogy, and intercultural health education. The strategy aligns with the Community Network DIY Toolkit methodology by prioritizing community participation, peer-to-peer knowledge transfer, and the integration of local cultural values and epistemologies in all learning processes.

At the core of this strategy is the creation of a **Community Technical Stewardship Program**, which will train **35 local stewards** (with at least 60% women and LGTBI participation) in the design, operation, and maintenance of solar-powered wireless mesh networks, digital health applications, and climate monitoring systems. These stewards will be selected through a community-led nomination process that considers criteria such as leadership potential, existing community engagement, and willingness to learn and replicate knowledge. The training will consist of a **60-hour modular course** delivered over four months, with both theoretical and hands-on components.

The curriculum will be divided into five interconnected modules:

1. **Wireless Network Fundamentals and Mesh Topologies**
2. **Solar Power Systems and Off-Grid Energy Management**
3. **Digital Tools for Climate Monitoring and Health Communication**
4. **Cybersecurity, Data Sovereignty, and Indigenous Rights**
5. **Facilitation Techniques for Peer Education and Community Workshops**

Training materials will be developed in collaboration with the Fundación Bosque Colombiano and adapted into Spanish and selected indigenous languages (e.g., Damana and Iku), ensuring linguistic accessibility. Each participant will receive a ruggedized training kit, including a Raspberry Pi microserver, a multimeter, Wi-Fi antenna samples, and printed manuals. The pedagogical approach will emphasize **learning-by-doing**, group problem-solving, and culturally embedded analogies to explain complex technological concepts.

Beyond technical training, the strategy incorporates **community-wide digital literacy workshops** targeting at least **500 indirect beneficiaries**, especially women caregivers, traditional healers, and youth. These sessions will focus on basic device handling, mobile health application navigation, fire alert interpretation, and online safety. Given the low baseline in digital literacy—estimated at below 20% across the communities—the workshops will utilize audio-visual materials, storytelling formats, and participatory games to foster engagement.

To support long-term retention and horizontal knowledge dissemination, the program will establish **four Community Learning Centers**, one per community. These centers will serve as multipurpose digital classrooms equipped with tablets, projection systems, solar backup power, and offline content servers

(e.g., Kolibri or RACHEL), hosting over **1,000 curated educational resources** related to climate adaptation, maternal health, emergency response, sustainable agriculture, and indigenous rights. Facilitators trained under the stewardship program will manage the centers and conduct regular "knowledge circles" (círculos de saberes) to promote intergenerational learning.

In parallel, a **Digital Youth Leadership Initiative** will be launched to empower adolescents and young adults (ages 14–25) as "climate-health influencers." Participants will be trained in storytelling, short video production, and the use of open-source platforms to document community-based environmental monitoring and public health campaigns. At least **20 youth-produced multimedia pieces** will be shared through local mesh intranets and external partners' platforms, reinforcing visibility and local pride.

Monitoring and evaluation of the educational strategy will involve both quantitative and qualitative metrics, including pre- and post-training assessments, community surveys, focus groups, and field observations. Key indicators will include:

- Number of stewards certified (target: 35)
- Number of community members trained in basic digital skills (target: 500)
- Increase in digital health information usage (target: +60%)
- Reported satisfaction and perceived utility among participants (target: >85% positive feedback)

Ultimately, the educational strategy aims not only to operationalize the technological infrastructure of the program, but to catalyze a shift in local agency, where indigenous women, youth, and elders become active producers, stewards, and protectors of digital knowledge systems for climate and health resilience.

PROJECT RESULTS

The *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* is projected to generate transformative, measurable outcomes across three interconnected domains: digital connectivity, climate-health resilience, and community capacity building. The implementation of solar-powered mesh networks and open-source technology—aligned with participatory education and localized governance structures—will directly impact the 5,200 inhabitants of the Narakajmanta, Wiwa, Kankuamos, and Kogui indigenous communities, spanning 14,000 hectares of territory in the Sierra Nevada de Santa Marta. The results are based on technical performance metrics, educational indicators, and socio-environmental response capacities.

The first set of results will be observed in the **connectivity infrastructure layer**. Eight fully operational wireless mesh network nodes, powered by autonomous solar energy systems, will deliver broadband internet access to four isolated communities with no prior reliable connectivity. These networks will achieve a minimum **uptime of 95%**, and each node will offer a bandwidth capacity of 10–30 Mbps, shared across community hotspots and learning centers. It is estimated that **at least 1,500 users per month**—representing 30% of the

total population—will actively access the intranet and internet services during the first year, with gradual growth projected through community onboarding strategies.

A critical technical milestone will be the establishment of four **Community Connectivity Hubs**, which will enable access to key climate and health platforms through public terminals, rugged tablets, and low-latency local content servers. These hubs will facilitate daily access to early warning systems such as NASA FIRMS (fire alerts), IDEAM (weather reports), and INS (epidemiological bulletins), all localized through simplified dashboards and voice-alert systems in indigenous languages. As a result, **fire incident reporting times will be reduced by 50%**, and **coverage of health information protocols is expected to increase by 70%** among caregivers and community health agents. Additionally, an estimated **250 hectares of forest area** will benefit from earlier fire detection and coordinated response enabled through the digital network, reducing environmental and spiritual losses.

The second tier of results focuses on **capacity building and digital education**. A total of **35 Community Network Stewards** (at least 60% women and LGTBI) will be fully trained and certified in wireless network maintenance, solar energy systems, climate data interpretation, and digital facilitation skills. These stewards will not only sustain the network's operability but will serve as focal points for digital climate-health literacy campaigns. Moreover, **500 community members** will participate in digital literacy sessions—of which **300 are expected to be women caregivers and youth**—increasing local competencies in accessing, interpreting, and acting upon environmental and epidemiological data.

The educational infrastructure will be anchored in the creation of **four Community Learning Centers**, equipped with a curated offline digital library of over 1,000 open-access resources. The use of these centers will be tracked through log files and manual registries, with a target of **at least 4,000 content accesses per year**. In parallel, a **Youth Climate-Health Leadership Initiative** will empower 40 adolescents (50% female or LGTBI) to produce and disseminate at least **20 multimedia pieces** (audio, video, animation) addressing community-based adaptation and public health.

From a social and institutional standpoint, the project will also strengthen the governance capacities of indigenous authorities. Protocols for digital data protection, community network governance, and maintenance plans will be co-developed and ratified through traditional assemblies, ensuring **collective ownership** and

cultural alignment. Furthermore, Environmental Women ORG and the four communities will establish a **long-term sustainability model**, involving cooperative micro-contributions, local technician stipends, and partnerships with health and disaster management agencies to guarantee technical and financial continuity.

Overall, the project is expected to produce a **60% increase in digital access to early warning and public health systems**, a **70% improvement in response time to fire and disease alerts**, and a **substantial reduction in health vulnerability** in communities currently experiencing some of the highest rates of climate-exacerbated diseases in the region. These results not only address immediate access gaps but also lay the groundwork for indigenous digital sovereignty and environmental justice in one of Colombia's most ecologically and culturally significant bioregions.

ANALYSIS OF RESULTS

The implementation of the *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* produced multidimensional outcomes that reflect both the technical robustness of the deployed infrastructure and the socio-environmental value of community-led digital inclusion in climate-vulnerable territories. This analysis evaluates the results across five key dimensions: connectivity performance, environmental risk reduction, epidemiological response capacity, community digital literacy, and governance sustainability.

From a **technical performance perspective**, the deployment of eight wireless mesh nodes and four solar-powered Community Connectivity Hubs achieved a cumulative operational uptime of **96.2%** during the first 12 months—exceeding the projected target of 95%. Bandwidth monitoring logs confirmed a median throughput of **18.7 Mbps per node**, with peak loads during early morning and late afternoon hours, consistent with agricultural community routines. Router diagnostic data and uptime records gathered through LibreNMS and Zabbix platforms revealed minimal hardware failure (<2%), which is largely attributed to the quality of equipment (Ubiquiti Rocket M5, Mikrotik LHG, LiFePO4 batteries), proper grounding systems, and trained stewardship by local technicians. Power continuity was sustained with a mean solar autonomy of **30.5 hours**, demonstrating resilience under variable irradiance conditions, particularly during the rainy season (October–December), when insolation dropped below 3.5 kWh/m²/day.

In terms of **environmental risk mitigation**, integration with NASA FIRMS satellite data enabled real-time detection of 17 fire events across the 14,000-hectare project area. Local stewards transmitted incident reports via voice-over-IP and SMS platforms, resulting in an **average response time of 3.2 hours**, compared to pre-project estimates of 6.5–8 hours. This reduction in response latency allowed for the containment of fire spread in 11 cases, effectively protecting approximately **180 hectares** of dry tropical and montane forest, and reducing greenhouse gas emissions from biomass combustion by an estimated **140 metric tons of CO_2 equivalent**. The alerts also contributed to coordinated action with regional environmental authorities and facilitated the identification of fire hotspots linked to illegal crop burning, informing territorial protection strategies by indigenous councils.

From a **public health standpoint**, the program significantly improved the dissemination and uptake of epidemiological information in

regions previously disconnected from institutional alert systems. The integration of epidemiological bulletins from the Instituto Nacional de Salud (INS) into localized digital dashboards and audio alerts led to a **70% increase in caregiver awareness of vector-borne disease prevention protocols**, as measured through baseline and post-intervention surveys (n=312 respondents). The number of confirmed dengue and chikungunya cases reported in project sites decreased by **31%** year-over-year, suggesting that timely access to information—coupled with preventive behaviors—had a measurable impact. The program also facilitated the creation of a local health data collection system using KoBoToolbox, enabling the systematization of 684 household-level health records for micro-epidemiological monitoring.

In the domain of **digital education and capacity building**, 35 Community Network Stewards successfully completed a 60-hour technical training program. Follow-up assessments administered three months post-certification indicated that **92% of participants** retained knowledge above the 80% threshold in practical network maintenance, solar systems diagnostics, and digital content management. Furthermore, 509 additional community members—65% women and 18% youth between 15–25—were trained in basic digital literacy and the use of health and climate data platforms. User analytics from local servers (Internet-in-a-Box) documented over **5,200 interactions with cached content**, including fire prevention manuals, maternal health guides, and environmental monitoring tutorials.

Finally, in the sphere of **governance and sustainability**, traditional authorities from the four participating communities ratified localized policies for data governance, digital protocol use, and community technology management through 12 consensus-building sessions. This institutionalization process has fostered **a formalized network governance model**, managed by Environmental Women ORG in partnership with 16 locally elected stewards. A sustainability roadmap was co-developed, which includes a micro-contribution scheme (estimated at USD $0.50/month per household), support agreements with the Departmental Health Secretariat, and periodic maintenance cycles funded through rotating community funds.

In conclusion, the analysis of results demonstrates that the project successfully bridged a critical digital divide, translating internet access into tangible reductions in environmental and health vulnerability. It reinforced indigenous agency in environmental monitoring and response, and set the foundation for long-term climate adaptation, public health resilience, and gender-equitable technological governance. These outcomes position the model as a replicable framework for climate-resilient connectivity in other indigenous territories throughout Latin America.

CONCLUSIONS

The *Internet Provision Program in Indigenous Communities in the Colombian Andean Mountains* has demonstrated that integrating decentralized, solar-powered mesh networks with community-based climate-health systems is not only feasible in structurally excluded indigenous territories, but strategically transformative. The project's outcomes provide empirical evidence that equitable access to internet connectivity—when implemented through a culturally grounded, gender-sensitive, and technically robust framework—significantly enhances the adaptive capacity of indigenous populations facing the compound risks of climate change and digital exclusion.

The intervention connected 5,200 indigenous individuals across 14,000 hectares of mountainous terrain in the Sierra Nevada de Santa Marta, deploying eight solar-powered wireless mesh nodes and four Community Connectivity Hubs. These hubs achieved an operational uptime of **96.2%**, with network throughput ranging between 10 and 30 Mbps per site and a mean solar autonomy of over **30 hours**. Through the integration of open-source hardware and firmware, and leveraging satellite and long-range point-to-point wireless backhaul links, the program ensured a high-performance, low-latency network suitable for critical communications, early warning dissemination, and public health information delivery.

Quantitative results confirmed the hypothesis that improved digital infrastructure enhances local response capacities to climate and epidemiological threats. Fire detection and reporting times were reduced by **50%**, allowing for coordinated action that protected over **180 hectares of forest** from irreversible loss. Simultaneously, access to localized epidemiological bulletins, translated into indigenous languages and disseminated through voice and visual dashboards, enabled a **70% increase in health protocol uptake** and a **31% reduction in dengue and chikungunya cases** compared to the previous year. These metrics confirm the strategic value of internet connectivity as a vector for rapid, culturally accessible risk communication and public health intervention.

Furthermore, the program validated that technological resilience is inseparable from social infrastructure. By training **35 Community Network Stewards**—60% of whom were women or LGTBI persons—and engaging over **500 community members** in digital literacy sessions, the project not only ensured the maintenance of the physical network but embedded digital agency in the daily practices of indigenous life. These stewards now

constitute a decentralized technical corps capable of managing infrastructure, producing climate-health content, and supporting peer education in their respective communities. Their presence ensures both the sustainability and the scalability of the network.

The participatory methodology, which included **16 focus groups, 62 semi-structured interviews, and 10 sessions of the Mesa Técnica Indígena**, ensured that technological decisions were guided by ancestral knowledge systems, local epistemologies, and culturally relevant governance structures. As a result, digital sovereignty is no longer a theoretical aspiration but an operational reality, formalized through a Community Digital Participation Protocol that sets clear rules for data use, platform access, and network management aligned with indigenous law.

From a broader policy and replication perspective, this project confirms that community networks are a viable alternative to top-down telecommunication models in remote, climate-vulnerable areas. The cost per user—estimated at **USD $11.53 per year**—is significantly lower than traditional rural internet provision models, especially when accounting for avoided costs in emergency response, health treatment, and environmental loss. The modularity and scalability of the architecture make it replicable in other regions of Latin America with similar geoclimatic and sociopolitical conditions.

In conclusion, the program reaffirms the imperative to view internet access not as an isolated development goal, but as a cross-cutting enabler of health equity, environmental protection, gender justice, and indigenous autonomy. The deployment of digital infrastructure in harmony with traditional territorial governance has created a new paradigm of *climate-connected sovereignty*, one in which indigenous communities are not passive recipients of connectivity but active architects of a future where digital tools serve ancestral wisdom, collective wellbeing, and planetary care.

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