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Weathering Nepal's Climate Crisis with Solar Irrigation

Introduction

Nepal's landscape tells the story of its people. With the greatest altitude change of any location on Earth—from the fertile Terai lowlands, to hilly midlands, to the famous Himalayan mountains—its geography and climate is as diverse as its history. For generations, the country's economy, livelihoods, and food security have relied on agriculture, with the majority of Nepal's modern workforce dependent on farming. Farmers have traditionally relied on rainfall for crop irrigation, but today, climate volatility has destabilized this balance. Monsoon summers have gotten wetter, winters drier, and extreme weather events more frequent. This essay will examine climate volatility as the critical factor affecting agricultural productivity and food security in Nepal, and explore the feasibility of implementing solar irrigation pumps as a solution to this challenge.

Country & Family

Nepal, a landlocked country between India and China, has a population of 29 million and is perhaps best known for being home to Mount Everest. The alpine mountains, temperate hills, and subtropical Terai make up Nepal's three climate zones, with average temperatures ranging from sub-zero to over 40°C respectively. About 80% of the country's inhabitants live in rural areas (World Bank), with 27% of Nepal's land being cultivated (TE) and the majority of agriculture occurring in the Terai plains (Shakya).

In recent years, Nepal has considerably reduced once-high levels of multidimensional poverty, caused by the Maoist Party's political conflicts and the turbulent transitional decade that followed. The poverty rate—once 42% in 1996—has since nearly halved, partly due to the evolution of a stable parliamentary democracy (BMZ). However, Nepal is still ranked 76th out of 114 countries on the 2021 Global Hunger Index (NNFSP) and 146th of 192 countries in the 2022 Human Development Index—the third-lowest ranking country in South Asia (WFP). Approximately 7 million of the population live under the national poverty line, and 4.6 million people remain food-insecure (NNFSP). Rural disparities persist—food insecurity is far more prevalent, only 3% of rural youth have internet and/or computers, and only 10% complete higher secondary education. Similar divides also exist in healthcare, electricity, and other utilities (Georgina), where failing infrastructure and unequal electrification hinder rural access.

Many paths of employment in Nepal—like construction, manufacturing, commerce, and transportation—remain short-term, involving high instability and precarious working conditions. Thus, nearly 80% of households and 70% of employment are still dependent on the agriculture sector (IFAD). Average annual wages range from 31,362–128,454 NPR (\$227–930), with rural salaries on the lower end (Paylab). Agriculture—like rice, grains, and vegetable oils—also drives 54% of Nepal's exports, while

textiles contribute an additional 20% (Sela). However, agriculture only contributes one-third of GDP, since most farming is subsistence-based.

Farming is often a family affair; with 70% of Nepal's families involved in family farming (FAO), the typical subsistence family consists of 4.7 people, and each subsistence farm is generally smaller than 1 hectare (approximately the size of a football field) (IFAD). Most families are patrilineal, with men handling labor-intensive chores like plowing and terracing (Nepali Times). Regardless, farming is a collective effort—elders, women, and children all contribute to subsistence farming, which is crucial during planting and harvesting seasons. Outside of subsistence farming, families also access food through local markets (Wendelin).

Agriculture is highly weather-dependent, with the “dry season” lasting from October to May (Wendelin). The farming calendar involves monsoon rice cultivation, winter crops like wheat and mustard, and vegetables. The average Nepali diet includes rice, potatoes, and legumes, with low consumption of animal products (Campbell et al.). Cooking methods vary by region, often using open flames and clay ovens—foods are grilled or fried in the Terai area, and steamed or boiled in mountainous areas (Darrah). Nepal's national dish is dal bhat, a nutritious lentil curry (Thirdeye) commonly consumed across the country.

As Nepal's population growth is projected to reach 36 million by 2050, urbanization and land scarcity are straining already limited agricultural land (CIAT). Consequently, maintaining agricultural production, water usage, and sustainability have been increasingly difficult. These challenges are further intensified by Nepal's most pressing issue: climate volatility.

Challenge & Impact: Climate Volatility

Climate volatility represents Nepal's largest vulnerability affecting agricultural productivity, household income, and food security. The Global Climate Risk Index 2021 has designated Nepal as one of the ten countries most severely affected by climate change, having faced multiple devastating earthquakes, monsoon rains, and droughts in recent years (Eckstein et al.). Presently, climate vulnerability is only worsening—Nepal could lose up to 10% of its GDP by 2100 absent proper climate adaptation (ADB).

Specifically, poor existing irrigation systems result in only 20% of agricultural land having year-round irrigation, leaving farmers dependent on unpredictable monsoon rains (Risal et al.), which account for 60-90% of Nepal's annual precipitation. This dependency has been detrimental for food security; in 2022, after record-level heat waves and a delayed monsoon season, thousands of farmers faced declines in rice production (Joshi). Conversely, heavy monsoon rains in 2021 caused farmers to suffer losses of 11.87 billion NPR (\$93 million), with 90,996 hectares of paddies completely destroyed. Despite government payouts to paddy farmers, the effects were still evident; for one, submerged swaths of ripe crops also netted less value in markets (Prasain).

Nepal's climate shocks and persistent stressors disproportionately impact vulnerable populations. Children and the elderly faced higher mortality rates during floods and other extreme weather events (IPCC); low income households in Nepal's middle hills region suffer greater damages from climate

hazards than wealthy households (Gentle); and lower caste families, women and other marginal groups in the Himalayan villages in Nepal are more vulnerable to climate change (Macchi), facing greater difficulties adapting to climate shocks while managing household responsibilities.

Solutions & Recommendations

Agrovoltaic Irrigation using Solar Irrigation Pumps (SIPs)

One potential solution to stabilize Nepal is agrovoltaic irrigation—an emerging system that uses solar panels to generate electricity for water pumps, decreasing the dependence on grid electricity and fossil fuel-powered systems. Solar-generated electricity powers a motor that draws water from underground, lakes, canals, or rivers for irrigation and household use (Va). Excess electricity generated by the panels can be stored in batteries or tanks, which powers the irrigation pumps and supplies water when sunshine is not available (Fig. 1).

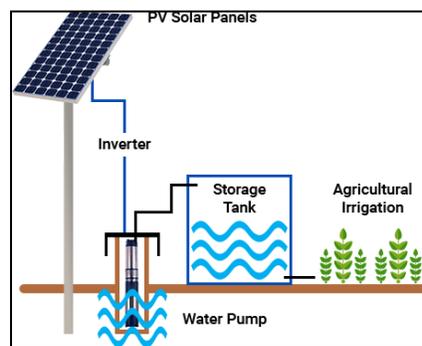


Figure 1: Diagram of solar irrigation pump (SIP) (Telco)

This recommendation is uniquely suited for Nepal, a country that has over 300 sunny days annually with an estimated annual solar generation potential of 50,000 TWhs (7,000 times greater than Nepal's current electricity consumption) (Koons). Solar photovoltaic costs have declined by 82% since 2010, making it an increasingly attractive option for rural farmers (IRENA). In comparison to other forms of renewable energy, like hydropower, developing solar infrastructure is half as costly, requires far less time to complete, and is less environmentally disruptive during construction (Aryal). These factors make agrovoltaic systems an affordable and scalable solution.

Solution Feasibility

In order to make this recommendation feasible, limitations and leadership must be addressed. On the supply-side, one limitation is the **lack of technical support and infrastructure supporting SIPs**. Conventional diesel pump systems have the advantage of an established rural distribution network, which pushes Nepali farmers to prefer diesel pumps as the norm. Thus, a large-scale solution must create a similar distribution network dedicated to solar irrigation systems—one potential recommendation can involve Nepal's government contracting international organizations, like the International Water Management Institute (IWMI) to train existing technicians to repair and maintain SIPs (Shrestha). In some cases, it is also possible to retrofit existing pumps with SIP inverters (Hobertek) or convert existing

diesel-pump operators into SIP entrepreneurs, which can allow for a more gradual transition between technologies.

Lack of supply presents another problem as well---the IWMI found that in 2016, after Nepal's government launched subsidies to support SIPs, demand for subsidized units overtook supply by ten-fold, and high up-front costs and the limited budget of the subsidy program have discouraged wider adoption. Thus, to combat the mismatch between subsidy-driven demand and limited supplier capacity, international actors, like foreign investment from energy companies and funding from the World Bank, play crucial roles in advancing Nepal's solar infrastructure. Luckily, enthusiasm about SIPs has recently been on the rise from external stakeholders—for example, China's Risen Energy Company is currently building Nepal's largest solar pump (Koons), a pilot in Nepal's Sarlahi district received financial support from the Government of Japan, and the World Bank recently approved two projects aimed to enhance Nepal's irrigation services and electricity distribution in May 2025, totaling \$257 million.

Another limitation is short-term cost; although maintenance costs of SIPs are up to four times lower than diesel pumps (Mishra) and operational costs are zero (as it runs on solar radiation), making SIPs cheaper overall, the upfront installation of photovoltaic panels remains costly. Even with Nepal's 60% subsidy for SIP installation, many rural farmers find these costs unaffordable. To combat this, large-scale implementation should include greater financial assistance and government support for farmers—for example, The Himalayan reported 40% of farmers surveyed by IWMI received SIPs for free. Additionally, farmers from Nepal's Parsa district reported paying only 5000 rupees for site preparation, with no direct cost for the pump itself (Kafle and Mukherji).

Given the potential financial strain that SIP implementation can put on farmers, education on financial literacy is also incredibly important. In Bihar, India, where SIPs have seen localized success, farmers show stronger financial literacy and collective trust than typical Terai's farmers (**Shrestha**). Thus, creating localized opportunities for investment, like village-level savings groups, offering workshops on budgeting for irrigation investments, and encouraging entrepreneurship---such as small-scale pump rental or maintenance services---can relieve the financial stress of SIPs.

Thus, when looking at empirical successes of SIP integration, it almost always requires partnerships with local communities, organizations, and utilities. One SIP pilot in India's Gujarat region connected solar pumps to the electricity grid, while simultaneously integrating a "25-year agreement with the local power utility to buy-back surplus power" (CGIAR). Initiatives like these led to a multi-billion dollar initiative from the Government of India focused on developing solar irrigation. Collaboration has always been a necessity for any successful policy implementation, and the citizens of Nepal play a crucial role alongside government intervention in the fight against irrigation and climate volatility. Through participating in pilot programs like the one in Gujarat, to advocating through the media, social campaigns, and local forums, Nepal can amplify the voices of local farmers in the journey to sustainable development.

Impact

Looking to the past, small-scale implementations of agrovoltaic irrigation have empirically been successful; for instance, the International Centre for Integrated Mountain Development ran a year-long

pilot project in 2015 in Nepal's Saptari district, which is highly vulnerable to climate shocks. Three solar irrigation pumps (SIPs) saved 1000 liters of diesel, increased irrigated land by 30%, and increased cultivation of dry season vegetables (Shrestha). Similarly, the Sunakothi-based Chhahari Agriculture Single Women Firm initiative implemented a micro-SIP in 2024, and found that climate-resilient irrigation systems were not only easier to maintain but also less vulnerable to natural disasters (Adhikari).

In nearby countries facing similar irrigation inconsistencies, like Indonesia and Pakistan, SIPs have also proven successful. After SIP implementation, Java's Kricing Village saw rice production nearly triple, from 1.7T to 5T. From town calculations, SIPs were sufficient to irrigate 70-80 hectares (OneEarth). Similarly, an analysis of 1,080 growers in Pakistan found that SIP adoption significantly enhanced farmer income, due to increases in agricultural yields (Khan). In 77% of cases in the Indus Basin, farms using SIPs extracted more water than their diesel counterparts under comparable conditions (Jamil).

Outside of the direct agricultural benefits, SIPs also have additional benefits in alignment with UN SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), since the shift to renewable solar energy reduces fossil-fuel-related emissions. Additionally, the surplus electricity generated can be stored and sold back to the power grid, providing an additional stream of income. In fact, in India's Gujarat region, a power purchase guarantee has been a strong incentive for farmers to adopt solar pumps (Parvaiz). Consequently, better irrigation and agricultural yields and food security have incredible spillover effects. In Nepal's Sudurpaschim Province, increased income and production have enabled women to meet household expenses and pay for their children's education, which they could not afford previously. The consistent availability of fresh vegetables has also contributed to the nutrition of the province's families and community (Shrestha). Not only does an additional stream of income cover necessary expenses, but farmers in India's Bihar province have also seen the strengthening of gender equality after the implementation of SIPs. Women and other marginalized farmers are often the beneficiaries of this additional entrepreneurial opportunity, empowering them to take on traditionally male-headed roles like business management and increasing their financial independence as a whole (Revolve).

Future Innovation Possibilities

Looking towards the future, solar agriculture can also go beyond replacing diesel pumps. One of the most promising innovations of agrovoltaic irrigation is dual land use, where crops are grown underneath solar panels (Fig. 2).

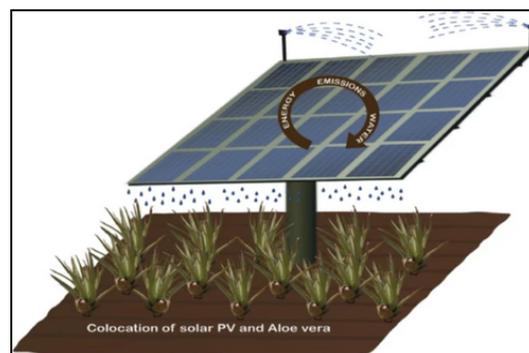


Figure 2: Diagram of dual land use PV system (Singla et. al)

Dual land use provides shade for leafy vegetables, seasonal fruits, and crops that struggle in arid, dry soil, which is especially important during Nepal's frequent droughts. Nepal's Sarlahi district has developed an SIP pilot to include dual land use, and it now provides electricity to the entire village, drinking water, and an additional stream of income. Consequently, patient care in the area, once dependent on "torchlights for patient care", now can "handle complicated cases with confidence" due to access to an uninterrupted power supply (UNDP).

Advances in artificial intelligence also have the potential to revolutionize agrovoltatics by using algorithms to monitor large datasets—ranging from weather patterns, solar irradiance, soil moisture, and plant health—in order to identify ideal panel placement, tilt, and spacing. By optimizing water usage and sunlight capacity, AI applications can reduce natural resource waste. Empirically, a four-year pilot in India's Maharashtra's region has integrated AI into the agrovoltaic process, cutting water usage by 30% and increasing crop yields by 15% (Hassan).

All in all, with the ever-decreasing price of solar panels, these recommendations make it possible for agrovoltaic irrigation to become a viable solution for Nepali farmers.

Conclusion

In Nepal's continued battle with climate volatility, farms are one of the many things at stake. The effects of increasingly extreme monsoon rains and droughts are most visible on agriculture and water availability—from the livelihoods of 70% of Nepalis, to the food security of tens of millions, to 10% of the national GDP, Nepal cannot afford to lose. Still, a promising solution exists: developing solar irrigation systems can provide year-round water access for farmers and invest in long-term renewable electricity generation. With responsible governance, including solar subsidies for farmers, strong inter-organization collaboration, and the creation of farmer incentives, this solution can succeed.

History proves that Nepal's agricultural traditions have always resulted in resilience—from the terraces carved into its hillsides to the indigenous crops that have nourished generations. With modern adaptations, the Nepali government can combat climate volatility and feasibly work towards ensuring food security for all.

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