Tackling Water Scarcity in India Through Innovative Finance

Financing Solar-Powered Drip Irrigation Through Intergenerational Self-Help Community Groups

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1. Introduction

This project focuses on reducing water use in water-scarce areas in light of climate change, preserving drinking water for essential use, and managing farmers' spending for irrigation through community empowerment. Optimal water management for the local context will be incentivized in the form of non-profit lending options with an equity component, administered through intergenerational self-help community groups, with a blended finance structure to support locals in enhancing the timing of irrigation for plants, thus increasing the yield of a specific crop, and harvesting period. Such sustainable water drainage systems can come in the form of drip irrigation.

Intending to cross the valley from impact to return, the project includes an equity component, covering part of the solar drip-irrigation infrastructure beyond debt financing. While this stake is initially provided by participating pension funds, the project encourages bottom-up funding within the self-help group. Financing streams, water allocation monitoring, and assessment are administered by the local community groups but supervised by a multi-stakeholder advisory platform.

The focus on local water management through partnerships reaches beyond agriculture. Water efficiency has tremendous spillover effects. Women will have to fetch less water and have more time for education and productive activities. In addition, increased yields will boost farmers' wealth.

2. Review

Improved water management contributes to multiple sustainable development goals simultaneously. It is crucial to avoid wasteful use of water to fulfil the essential need for water, sanitation, and hygiene (SDG 6). Especially for women, who are responsible for fetching water and suffer from a lack of reproductive hygiene in many parts of the world, potential in education and workforce can be set free, thus increasing family wealth, via responsible water management (SDG 1, 3, 4, 5, 8). Additionally, responsible water use is essential for achieving zero hunger (SDG 2) and avoiding water wars due to climate change (SDG 13).

Agriculture uses most water worldwide. In India, according to AQUASTAT, the FAO database on global irrigation use, "rice is the main irrigated crop in the East (49 percent of regional AHIfull[1]) and the South (59 percent). Contrary to that, wheat is the main irrigated crop in the West (52 percent) and the North (both 32 percent)",[2] where the project would start as it will have the highest impact on communities there. Hence, an increased productivity and efficiency of irrigated agriculture in India is urgently needed, especially in light of the wheat crisis intensified by the war in Ukraine. Moreover, maximising

[1] *AHIfull* stands for "Harvested crops irrigated by full control irrigation"

[2] See the excel sheet downloaded from "Food and Agricultural Organisation of the United Nations. 2012. AQUASTAT - FAO's Global Information System on Water and Agriculture. FAO. Link."

the yield of Indian agriculture is essential for people's nutrition worldwide, justifying this project's focus. According to the World Bank, 20% of total cultivated land globally is irrigated agriculture contributing 40% to total food production.[3] Hence, while general irrigation makes agriculture double profitable, drip irrigation reduces water use by 60 percent and increases crop yield by around 90 percent, compared with conventional irrigation methods.[4]

Consequently, the usage of water for water-intensive crops (rice, sugarcane, banana, and cotton) decreased by 45%-50%, which, however, yielded up to 25%-30% more in a year.[5] Further advantages of drip irrigated cotton compared to flood irrigated cotton include, for example, decreased electricity consumption, a higher seed rate of cotton, and an ultimately higher production per hectare (see Annex 1). But drip irrigation systems are expensive, particularly in off-grid environments where they sometimes cost farmers more than $3,000 (approximately 230 000 rupees) per acre to install.[6] However, in 2017, MIT researchers have found a way to cut the cost of solar-powered drip irrigation systems by half.

Economically, investment in drip irrigation infrastructure has proven successful, incentivized through infrastructure subsidies, clearing titles to water rights, marginal cost pricing, and non-volumetric pricing. On an institutional level, incentives can come from regulatory measures, transboundary agreements, and water user associations.[7]

The need for drip irrigation financing and the promise of existing technology seems uncontested in India. However, many providers have already tried to fill this niche. Hence, it is worth reviewing existing solutions for this project to offer a real surplus value.

3. Challenge Definition

The agricultural sector is of utmost importance for India in two ways: First, the sector still employs more than 42% of the country's workforce, according to the latest estimates, and thus serves as a baseline for the survival of the poorest.[8] Second, the country became self-sufficient in food production to feed its population of more than 1.3bn people but still has one of the world's highest shares of

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[3] The World Bank. 2020. *Water in Agriculture*. The World Bank. Link.

[4] Gulati, Ashok, and Rikita Juneja. 2018. *Innovations and Revolutions in Indian agriculture - A review.* Journal of Agricultural Science and Technology, B 8, 473-482.

[5] Soman, P., Prasad, M. S., Balasubramaniam, V. R., Singh, S., Dhavarajan, C., Patil, V. B., and Sanjeev, J. H. A. 2018. *Effect of Drip Irrigation and Fertigation on the Performance of Several Rice Cultivars in Different Rice Ecosystems in India*. International Journal of Agriculture Sciences 10 (14): 6672-5.

[6] Chu, Jennifer. 2017. *Watering the World.* Massachusetts Institute of Technology. Link.

[7] Ward, Frank A. 2010. *Financing Irrigation Water Management and Infrastructure: A Review*. International Journal of Water Resources Development. Vol. 26, No. 3, 321-349.

[8] World Bank Data. 2021. *Employment in Agriculture (% of total employment) (modelled ILO estimate) - India*. The World Bank. Link.

undernourished people. However, the food supply and farmers' subsistence are endangered by various factors. In order to reach its self-sufficiency in grain production, the country opted for resource-intensive production, primarily in terms of water. A sharp decrease in groundwater levels is accompanied by land degradation and desertification.[9] Climate change further increases the likelihood of more severe heat waves and water shortages, which the country is currently experiencing. India expects wheat arrivals to be 20% lower in 2022 than in 2021.[10] The war in Ukraine has significantly worsened the situation, and India’s decision to ban exports led to an immediate increase in global wheat prices. It contributes to food insecurity all around the world.[11] Those uncertainties increase farmers' volatility and risk for financial stewardship and planned investments.[12] Climate change, corresponding rising temperatures, and declining precipitation levels are estimated to be reflected in income losses of 15 to 18 percent on average and 20 to 25 percent for non-irrigated areas. Given declining groundwater levels and increasing water scarcity, India thus needs to implement efficient irrigation measures that yield “more crop per drop.”[13] Financial mechanisms to provide planning reliability are required. Finding new ways of financing technological upgrades must be at the start of every consideration.

4. Financing Solution

From an economics of development point of view, a microcredit scheme sounds like the go-to way. Classical microfinance structures, however, have been applied intensively over the last couple of decades, but the impact of such is questionable and yet to be proven.[14] Furthermore, blended finance approaches with a focus on debt have been exhausted. A combination of ODA in the form of equity with pension funds and foundations, however, could significantly leverage substantial amounts of capital from public and private investors to flow from the Global North to the Global South, where it is needed most for sustainable development. To provide flexibility to locals concerning the timing of irrigation for plants, independent from water prices, and for investments in water-saving drip irrigation technology, this project suggests a funding scheme for providing farmers with the possibility of equity investments into their drip irrigation system. The proposed blended finance structure

[9] Food and Agriculture Organisation of the United Nations. 2022. *India at a glance*. FAO in India. Link.
[10] Livingston, Ian, and Kasha Patel. 2022. *Heat Waves Break Monthly Records in India and Continuous to Build*. The Washington Post. Link.
[11] Hoskins, Peter. 2022. *Ukraine war: Global heath prices jump after India export ban*. bbc news. Link.
[12] Willingham, Caius. 2021. *Promoting Climate-Resilient Agricultural and Rural Credit*. Center for American Progress. Link.
[13] Syngenta Foundation. 2022. *India*. Syngenta Foundation for Sustainable Agriculture. Link.
[14] Banerjee, Abhijit, et al. 2015. *Six Randomized Evaluations of Microcredit: Introduction and Further Steps*. American Economic Journal: Applied Economics, 7(1): 1–21.

focuses on equity, while still partially relying on debt. It actively engages a multi-stakeholder group, such as pension funds, upfront investors in the form of foundations, and local community actors for long-term solutions. The projects themselves must achieve a particular scale: At least 25-30 acres of land have to be covered by the drip irrigation system to be effective over the long run and use its economies of scale.[15] This prerequisite results in high initial investment costs for the farmers. Thus, for small farmers to tap into specific loan programs that would benefit them, they have to first organise themselves in groups, so-called self-help groups, and second, would have to, nevertheless, provide a certain amount of capital to be eligible for loans from larger banks. The amount differs from bank to bank and is between 15%-25% of the project costs in the State Bank of India case.[16] These often too high capital requirements should be eased through the following financing solution.

For pension funds to step into equity investments, the first tranche of capital that finances 20% of the project costs comes from foundations or government development agencies and transfers these 20% rights to the farmer's community.

An additional 40% are financed by pension funds or family offices, with a lower return expectation through their impact portfolios. In conjunction with the pension funds and family offices, foundations and government development agencies are, therefore, setting up a special purpose vehicle that invests together into the projects and is equipped with a starting capacity. This 40% represents an equity investment; without profit participation by the pension funds, the self-help groups can pay that out over the long term. After repayment from the farmer's group, the starting capital is reinvested into new projects to scale up over time.

The financing group collectively borrows the remaining 40% of the financing costs at low prices from banks (see State Bank of India). Under the assumption that the increase in income amounts to 30%, for example, for cotton farmers from 230.00 EUR to 300.00 EUR,[17] the farmer's community would be able to repay the bank credit over four years with a yearly interest rate of 3.6% (see State Bank of India) and buyout the pension fund equity investment after eight years (see Annex 2 & 3: Investment Projection). For 25 acres of land (second case for 50 acres), yearly credit repayment is equal to €1,750.00 or ₹145,250.00 with an average interest rate payment of €157.50 or ₹13,072.50 for the first four years. Therefore, the interest payments to repay the debt are not covered in the financing model by the increase in production income but would have to be covered by the regular expenses of the

[15] Syngenta Foundation. 2022. *Developing Irrigation Infrastructure on the Build, Operate and Transfer (BOT) Model*, Syngenta Foundation for Sustainable Agriculture. Link.
[16] State Bank of India. 2022. *Composite Minor Irrigation*. State Bank of India. Link.
[17] Laudes Foundation. 2018. *Bridging the credit gap: Water sustainability through innovative financing*. Laudes Foundation. Link.

farmer's community or other financial means. As a result, the internal rate of return for the farmer's community remains negative (-1%) after eight years for both models (25 acres and 50 acres), although the loan is fully repaid. Only after 9 years, the investment pays off, with an IRR of 2%, which ultimately increases to 9% after 15 years when the drip irrigation system reaches the end of its lifecycle (see Annex 4).

In this equity-type model, farmer communities must be selected carefully, and more stringent monitoring applied. The recipient selection is made with on-the-ground workers from a local non-governmental organisation to identify risks and opportunities from sources of irrigation, natural circumstances, and overall livelihood opportunities. They can also better discuss with the recipients the investment amount, payments schedule, and train and support the farmers in management and agricultural-related aspects. This encompasses mainly financial literacy, water management, fertilizer usage, crop cultivation, and community aspects. Instead of demanding collateral, which has led to exploitation and land-grabbing in India, disclosure, and monitoring is necessary but also bear the potential to restrict freedoms.

Including self-help groups as a form of community lending to farmers for the project has several advantages. Not an individual has to bear the credit burden, but a group is collectively responsible for repayment. Additionally, issuers of the credit and financiers are in a position to overcome the challenges arising from asymmetric information. First, a possible lack of commitment through moral hazard is counteracted by the social pressure within the self-help group. Each individual has a vested interest in the repayment of the credit and thus simultaneously controls the other members of the group to contribute substantially and make faithful efforts for reimbursement. Second, by lending to a group instead of individuals, creditors avoid adverse selection and extending credits with a higher collective default risk and premium. Third, further aligning local loan officers' rewards with the overall success of the drip irrigation scheme increases their screening efforts and thus leads to a better selection of recipients. On the other hand, it increases their commitment and financial counselling assistance over the eight-year repayment schedule.[18]

5. Feasibility Assessment

a) Technical Feasibility (resources and expertise)

The main challenge of this project will be moving the idea of community-owned solar drip irrigation

[18] Cole, Shawn. et al. 2011. *Improving Financial Access for Entrepreneurs in Developing Countries - Evidence from a Serial Experiment with Commercial Bank Loan Officers*. IGC Policy Brief. Link.

away from philanthropy and donations to a return-generating model, bridging the so-called valley of death.[19] Comparative projects show a percentage of 70% donations, which is often unsustainable in the long term, compared to our 20% in pure grants, as detailed above. This is achieved via an equity option for buy-back based on an intergenerational financing model. Financial exchanges, such as the Chicago Mercantile Exchange (CME), have historically been based on such intergenerational reciprocity.[20]

Concerning the distinct growth stages of enterprises, we expect the project to have sufficient starting capital due to hype around drip irrigation financing as a way to tackle sustainability and inequality simultaneously.[21,22] This will be followed by so-called impact-first, middle ground investments that can boost emerging technologies. Social preferences are visible in demand from pension funds.[23] Trusted relationships and consistent impact measurement are essential to tapping into this funding space. Pula, an African farmer insurance, is a role model in stepping up from impact to return using the Credit Suisse accelerator.[24]

In addition to diverse capital sources, we target multiple actors for our advisory board to mainstream best practices. For example, possible advisory partners could be the GIZ, USAID, the Aga Khan Foundation, the NGO Pradan,[25] AU financiers,[26] and the aforecited Swiss Laudes foundation, in conjunction with the Credit Suisse accelerator structures.

b) Economic Feasibility (financial cost and benefits)

In comparison, a rental solar drip irrigation model costs 45 000 - 60 000 rupees per annum (see Case 3).[27] As introduced above, MIT's novel solar drip irrigation method reduces expenses by half, resulting in 105 000 rupees per installation. Hence profitability is reached after two years compared to the rental model.

[19] Murphy, L. M., and P. L. Edwards. 2003. *Bridging the Valley of Death: Transitioning from Public to Private Sector Financing*. National Renewable Energy Alboratory, NREL/MP-720-34036.
[20] MacKenzie, Donald, and Yuval Millo. 2011. *Constructing a market, performing theory: The historical sociology of a financial derivatives exchange*. in: The Sociology of Economc Life. 3rd Edition.
[21] Laudes Foundation. 2018. *Bridging the credit gap: Water sustainability through innovative financing*. Laudes Foundation. Link.
[22] Baruah, Litul. 2018. *Improving Farmer Livelihood, One Drip at a Time*. Laudes Foundation. Link.
[23] Bauer, Ruof Smeets. 2021. *Get Real! Individuals Prefer More Sustainable Investments*. The Review of Financial Studies, Volume 34, Issue 8, Pages 3976–4043.
[24] Credit Suisse. 2022. *Pioneers of Progress: Pula*. Credit Suisse. Link.
[25] International Finance Corporation (IFC). 2012. *IFC-Supported Au Financiers Reaches over 100,000 Small Business Owners in Rural India.* IFC. Link.
[26] AU Small Finance Bank. 2022. *About us*. Link.
[27] Shirsath, Paresh B. et al. 2020. *Compendium on Solar Powered Irrigation Systems in India*, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). New Delhi. Link.

The average Indian farm income is Rs 270 a day and Rs 8,337 monthly net, and therefore not much higher than the minimum wage in India,[28] with meagre income growth from crop cultivation. Based on our estimations on a similar project by the Laudes foundation, we assume that farmers used to spend around Rs 70,000-80,000 (EUR 930-1,060) a year on irrigation, making just Rs 10,000-15,000 (EUR 130-200) profit a month. After drip, they might increase their monthly yield to Rs 25,000-30,000 (EUR 330-400).[29] Hence, although the financial benefit from solar drip irrigation is undisputed, installation financing is a big hurdle.

Currently, most Indian farmers are small and medium enterprises, while only larger businesses can afford drip irrigation programs.[30] This leads to comparative advantages, which exacerbate inequalities. This project aims not to subsidise medium and large farmers further but to empower smaller actors through community groups.

c) Legal Feasibility

Government intervention in India has distorted the market, but subsidies such as GGRC do not provide sufficient financing support. Additionally, many farmers do not own documents for the land they plant, hence cannot apply for governmental support. While 100% subsidies via "small farmer certificates" exist,[31] loans are sometimes not given to people younger than 24 or with less than two years of residency.[32] Our project includes pro-bono services to assist with legal expertise in this complex environment. Agricultural land is governed at a state level, including rules on subsidies and credit. Therefore, we consider our project in one state, Madhya Pradesh, which is very much suitable for the model due to its large agricultural sector, potentially later adapting the model to other Indian states.

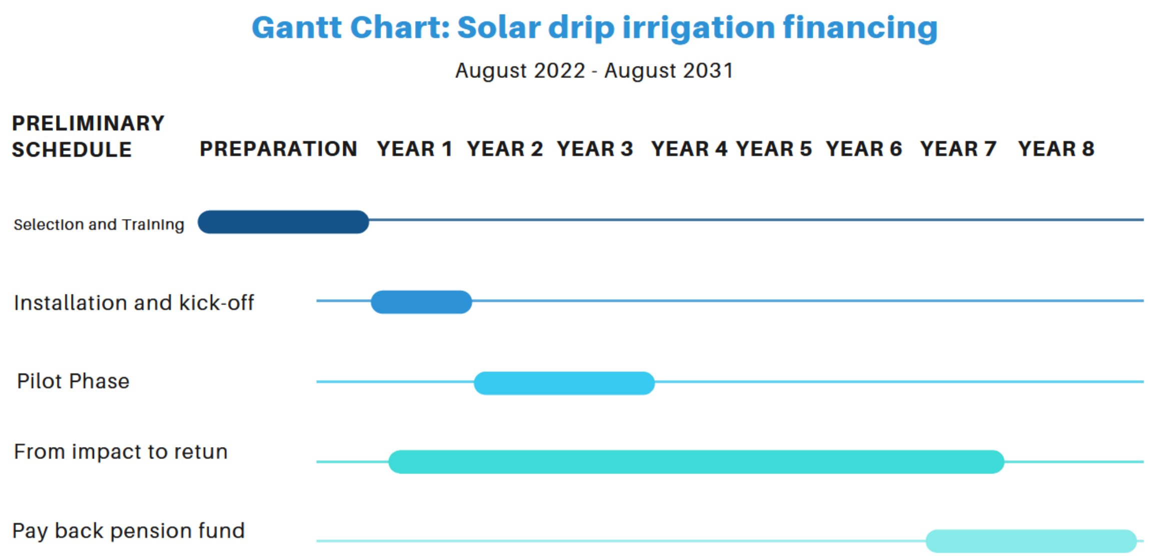
d) Operational and Time Feasibility

The project intends to reduce work hours for small and medium farmers and increase their comparative advantage by investing the hours set free by a technological upgrade in collective management via the self-help group. The social contract for this community network requires participants to take over tasks such as the pre-investment screening of new members, systems maintenance, and impact monitoring. Intensive training and external advisory via our multi-stakeholder platform is required mostly initially. However, our optimistically estimated lifetime of 15 years is based on technical support from the private sector,[33] and current technological development

[28] Narayanamoorthy, A. 2021. *Why farm income in Inda is so low*. The Hindu Business Line. Link.
[29] Baruah, Litul, 2018. *Improving Farmer Livelihood, One Drip at a Time*. Laudes Foundation. Link.
[30] Ibid.
[31] India Filings. 2022. *Small Farmer Certificate*. Link.
[32] Bank Bazaar. 2022. *Loan Against Agricultural Land*. Link.
[33] ICID. 2019. *FAO SPIS Report*. Link.

to ensure high quality and material longevity of the whole drip irrigation system.[34] So-called "drip-start ambassadors" are recruited from a community after the drip irrigation has turned profitable and will be sent to other communities.

Our monitoring is distinct from the IFC, which is criticized for neglecting social welfare in its SDG assessment, and traditional ODA with rules imposed on the private sector (see criticism Pereira, 2017: responsibility transfer, moral hazard). Instead, each community that we invest in will become an active project owner by setting its own rules, measures of success, and respective deadlines. These will be communicated to investors before capital is paid out. For orientation, please refer to the preliminary Gantt Chart below. In addition, to provide an incentive for competitiveness, visits of funders and the "drip-start ambassadors" of sister community projects will be organised twice annually for communities to "show off".



6. Conclusion

There are high hopes for drip irrigation financing in India. Still, inequalities have been exacerbated so far by a lack of technological upgrades for small farmers, unsustainable philanthropy, and debt-driven projects. Existing subsidies by the government do not suffice for small and medium agricultural businesses in India, and existing loan schemes bear the threat of leading to debt and expropriation spirals. We try to fill this gap by financing equity stakes through pension funds, which community self-help groups can buy back. An experienced advisory group complements active ownership of drip irrigation systems. The economic feasibility for especially the most vulnerable stakeholders and pension funds needs to be guaranteed from a democratic point of view.

[34] GIZ. 2020. *Solar Powered Irrigation Systems (SPIS)*. Link.

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8. Annex

Annex 1: Advantage of Drip-irrigated cotton compared to flood irrigated cotton[35]

Key stats: Drip irrigated vs flood irrigated cotton

Particular	Drip Irrigation	Flood Irrigation
Pump set (HP)	7.5	7.5
Number of rounds of irrigation per ha	48 ↑	6
Hours per irrigation round per ha	1.65 ↓	19.75
Electricity consumption (kWh/ha)	447.5 ↓	667.5
Seed rate of cotton (g/ha)	2,510 ↓	3,393
Cost incurred in weedicide and intercultural operations (Rs/ha)	4,275 ↓	6,682
Production in quintal/ha	23.35 ↑	18.37

Source: Research Analysis at CCS Haryana Agriculture University, Hissar , Agriculture Science Digest, 35 (4) 2015: 300-303

[35] Laudes Foundation. 2018. *Bridging the credit gap: Water sustainability through innovative financing*. Laudes Foundation. Link.

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Annex 2: Investment Projection for 25 acres of land

Investor	Capital Invested EUR*	Capital Invested INR°	Share	Interest Rate first 3 years	Yearly repayment first 4 years EUR	Yearly repayment first 4 years INR	Interest payments yearly first 4 years on average EUR	Interest payments yearly first 4 years on average INR	Yearly repayment second 4 years EUR	Yearly repayment second 4 years INR
New Financing Vehicle										
Up-front Investors	€3,500.00	₹290,500.00	20.00%	0.00%	€0.00	₹0.00	€0.00	₹0.00	€0.00	₹0.00
Main Investors	€7,000.00	₹581,000.00	40.00%	0.00%	€0.00	₹0.00	€0.00	₹0.00	€1,750.00	₹145,250.00
Farmer Community	€7,000.00	₹581,000.00	40.00%	3.60%	€1,750.00	₹145,250.00	€157.50	₹13,072.50	€0.00	₹0.00
OVERALL	**€17,500.00**	**₹1,452,500.00**	**100.00%**	**3.60%**	**€1,750.00**	**₹145,250.00**	**€157.50**	**₹13,072.50**	**€1,750.00**	**₹145,250.00**

* Costs per acre of land of drip irrigation: 700.00 EUR; Overall 25 acre of land
° Currency conversion of 1 EUR = 83 INR

Farmer	Additional income per acre per year (EUR)*	Additional income per acre per year (INR)*	Overall additional income per year (EUR)	Overall additional income per year (INR)
Cotton	€70.00	₹5,810.00	€1,750.00	₹145,250.00

* Assuming an increase from 230 EUR to 300 EUR (Laudes Foundation program)

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Annex 3: Investment Projection for 50 acres of land

Investor	Capital Invested EUR*	Capital Invested INR°	Share	Interest Rate first 3 years	Yearly repayment first 4 years (EUR)	Yearly repayment first 4 years (INR)	Interest payments yearly first 4 years on average (EUR)	Interest payments yearly first 4 years on average (INR)	Yearly repayment second 4 years (EUR)	Yearly repayment second 4 years (INR)
New Financing Vehicle										
Up-front Investor	€7,000.00	₹581,000.00	20.00%	0.00%	€0.00	₹0.00	€0.00	₹0.00	€0.00	₹0.00
Main Investors	€14,000.00	₹1,162,000.00	40.00%	0.00%	€0.00	₹0.00	€0.00	₹0.00	€3,500.00	₹290,500.00
Farmer Commun	€14,000.00	₹1,162,000.00	40.00%	3.60%	€3,500.00	₹290,500.00	€315.00	₹26,145.00	€0.00	₹0.00
OVERALL	**€35,000.00**	**₹2,905,000.00**	**100.00%**	**3.60%**	**€3,500.00**	**₹290,500.00**	**€315.00**	**₹26,145.00**	**€3,500.00**	**₹290,500.00**

* Costs per acre of land of drip irrigation: 700.00 EUR; Overall 50 acre of land
° Currency conversion of 1 EUR = 83 INR

Farmer	Additional income per acre per year (EUR)*	Additional income per acre per year (INR)*	Overall additional income per year (EUR)	Overall additional income per year (INR)
Cotton	€70.00	₹5,810.00	€3,500.00	₹290,500.00

* Assuming an increase from 230 EUR to 300 EUR (Laudes Foundation program)

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Master in International Affairs, IHEID
August 17, 2022

Annex 4: Internal Rate of Return for the Farmer's Community

COST VERSION 1; 25 acre of land

Farmer's Cash-Flow*		
	EUR	Rupee
Initial Investment	-€14,000.00	-₹1,162,000.00
Net Income Year 1	€1,592.50	₹132,177.50
Net Income Year 2	€1,592.50	₹132,177.50
Net Income Year 3	€1,592.50	₹132,177.50
Net Income Year 4	€1,592.50	₹132,177.50
Net Income Year 5	€1,750.00	₹145,250.00
Net Income Year 6	€1,750.00	₹145,250.00
Net Income Year 7	€1,750.00	₹145,250.00
Net Income Year 8	€1,750.00	₹145,250.00
Net Income Year 9	€1,750.00	₹145,250.00
Net Income Year 10	€1,750.00	₹145,250.00
Net Income Year 11	€1,750.00	₹145,250.00
Net Income Year 12	€1,750.00	₹145,250.00
Net Income Year 13	€1,750.00	₹145,250.00
Net Income Year 14	€1,750.00	₹145,250.00
Net Income Year 15°	€1,750.00	₹145,250.00

Farmer's IRR after	
1 year	-89%
2 years	-60%
3 years	-39%
4 years	-25%
5 years	-16%
6 years	-9%
7 years	-4%
8 years	-1%
9 years	2%
10 years	3%
11 years	5%
12 years	6%
13 years	7%
14 years	8%
15 years	9%

* Including the average interest payments for the first 4 years and assuming a steady income over 15 years

° Assuming the life-cycle of a drop irrigation system of 15years

COST VERSION 2; 50 acre of land

Farmer's Cash-Flow*		
	EUR	Rupee
Initial Investment	-€28,000.00	-₹2,905,000.00
Net Income Year 1	€3,185.00	₹264,355.00
Net Income Year 2	€3,185.00	₹264,355.00
Net Income Year 3	€3,185.00	₹264,355.00
Net Income Year 4	€3,185.00	₹264,355.00
Net Income Year 5	€3,500.00	₹290,500.00
Net Income Year 6	€3,500.00	₹290,500.00
Net Income Year 7	€3,500.00	₹290,500.00
Net Income Year 8	€3,500.00	₹290,500.00
Net Income Year 9	€3,500.00	₹290,500.00
Net Income Year 10	€3,500.00	₹290,500.00
Net Income Year 11	€3,500.00	₹290,500.00
Net Income Year 12	€3,500.00	₹290,500.00
Net Income Year 13	€3,500.00	₹290,500.00
Net Income Year 14	€3,500.00	₹290,500.00
Net Income Year 15	€3,500.00	₹290,500.00

Farmer's IRR after	
1 year	-89%
2 years	-60%
3 years	-39%
4 years	-25%
5 years	-16%
6 years	-9%
7 years	-4%
8 years	-1%
9 years	2%
10 years	3%
11 years	5%
12 years	6%
13 years	7%
14 years	8%
15 years	9%

* Including the average interest payments for the first 4 years and assuming a steady income over 15 years

° Assuming the life-cycle of a drop irrigation system of 15years

Annex 5: Overview of Solar Powered Irrigation Systems (SPIS)[36]

TABLE 1
Summary of SPIS configurations

Configuration	Description	Complexity	Adaptability	Remarks	Survey results
Direct pumping	PV panels and pump (with DC or AC motor) and controller with or without water storage (elevated) tank or reservoir and irrigation system (flood, sprinkler, micro-irrigation [drip], and irrigation machines). Maximum Power Point Tracking (MPPT) and other electronic/software features improve efficiency. Variable motor speed and pump volume during the solar day and cloud interfaces. Solar-irrigation controller uses volume meter (not timer).	Relatively simple	Adaptable to all sizes and irrigation methods as well as requirements. Fertigation (injection of fertilizers, soil amendments and other water-soluble products into an irrigation system) can easily be integrated, as well as water treatment and cleaning chemicals – e.g. for drip.	Most-used system across the world; water to wire efficiencies of more than 50% available from efficient systems. Should be used on volume basis. Needs speed control for irrigation machines.	27 out of 54 participants report that the water is used for other purposes than irrigation.
Multi-use systems (on-farm use)	Same as above plus other uses at times, when no pumping is required (milling, grinding, sawing, food processing, cooling, etc.)	Medium to complex	The controller is usually optimized for the pumping system – energy needs of other uses must logically follow the pump; the motors should have the same voltage as the pump motor and DC/ AC mode.	Use of batteries only with separate systems!	22 out of 54 participants report multi-use systems in their environ-ment.
Pumps in mini-grids (ommunity-based)	PV panels (generator) supply the power to various different uses (pumping, solar home systems, etc.)	More complex, technological solutions are being developed	Different uses can be accounted for (and paid for) – but important compromises on efficiency are necessary! Solar energy can feed into the grid as well and generate income, if not required for other uses.	Will the considerable loss of pump system efficiency make up for the advantages of a mini-grid?	
Hybrid systems	Solar pump systems work in parallel with the electrical grid and/or diesel pumps. Normal night-time use or energy blends at low radiation level for high season (water demand).Peak demand for solar generator size reduced.	Medium to complex	Various configurations exist, e.g. 1. Simple switching over to an external energy source when solar is not producing the required energy; 2. Supplementing the missing power (from solar) gradually as needed. Automatic and manual systems. Often used with old existing diesel pumps.	Often used to decrease electricity/ fuel charges. Feed into the electricity grid might be possible.	
Additional use (non-energy use)	"Lost space" under PV panels can be used for a range of high-value crops, (e.g. spinach, medicinal plants) or as shading for animals. Alternatively, the PV panels can be placed floating on water.Solar generator on roof of buildings or on top of water tanks.	Simple	Even sheds for animals can be constructed underneath the PV panels. Complex construction; no later extension possible.	Floating systems improve efficiency as they have a cooling effect on the panels (and decrease evaporation of the water body).	7 out of 54 participants report additional (non-energy) use.

Source: authors' compilation, based on material from GIZ, Toolbox on Solar Powered Irrigation Systems

[36] Hartung, Hans, and Lucie Pluschke. 2018. *Benefits and risks of Solar Powered Irrigation - A Global Overview*. Food and Agricultural Organisation of the United Nations & Deutsche Gesellschaft für Internationale Zusammenarbeit. Link.