
Artificial Glaciers in Ladakh

A socio-economic Analysis

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1. Ladakh

Ladakh forms the North-Easterly region of the Indian state of Jammu and Kashmir, bordering China/Tibet to the East and Pakistan to the North. In terms of land area, Ladakh forms around 2/3rd of the state and in terms of population it is a mere 2%. The region is split into two districts, Leh and Kargil, which in turn are split into 19 development blocks. There are significant variations in climate within the region as well. Most of the Nubra and Sham valleys, for example, are at lower elevations and experience a shorter and less harsh winter and most villages are able to get two crops in the relatively longer summer. The Changthang region on the other hand, where villages are located between 13,000 to 15,000 feet above sea level and goes through an 8 month winter with temperatures dropping down to -45°C , are largely pastoralists and are able to practice limited or no farming. In all parts, however, winter temperatures generally fall below -15°C and there is very little rain, with winter snowfall making up for a bulk of the average 10cm annual precipitation it receives. The region is classified as a 'high altitude desert' and is one of the highest, driest and coldest inhabited places on earth. Very little grows wild in the region and agriculture and the allied sectors remain the main livelihood source for most of the 50,000 inhabiting families even though average agricultural land is less than a hectare per family and most parts of the region manage to harvest just a single crop.

2. Artificial Glaciers

For a population whose survival is totally dependent on the snow melt from the glaciers, both for drinking water and for irrigating the fields, artificial ways of forming glaciers is not exactly a recent invention as some seem to believe. Even a century back, people in the region 'grafted' glaciers through a complex and tedious process of mixing many ingredients including 'masculine' and 'feminine' pieces of glaciers and compressed snow, which would be placed in a shady area high up on the mountains. This patch would grow with each fresh fall of snow and in a few years would resemble close to a regular glacier. In fact, folklore has it that in parts of the Hindu Kush Mountains now in Pakistan, artificial glaciers were first grafted way back in the 12th century to block the passes against a possible conquest by Gengis Khan, much in the lines of the Great Wall of China.

The other, currently more popular, form of artificial glaciers is the one built on or close to the village stream fed by perennial natural springs, by building structures to store the glacier melt during the winters in the form of ice. One of the techniques involves building retention walls that are 3-6 feet high at regular intervals in the stream itself. This method is very simple and has been used by village communities from generations back and is very effective if the stream is not exposed to direct sunlight in the winters. The other technique much popular and in use now and one that made the term 'artificial glacier' popular in the media is a variation of this age old technique. In this case, water is diverted from the main stream through a narrow diversion canal to a nearby valley facing north or remaining largely under shade through the winters. The water is let into this valley and allowed to freeze through a series of walls built much in the lines in the previous case. This technique is best suited in cases where the stream remains exposed to the sun during the winters not allowing ice to form. In terms of methods and finer details, these techniques could be further classified (technical details in Cabon and More).

Water freezes in the artificial glaciers in the months of December to February and starts melting from the middle of March, just in time for the pre sowing irrigation of the fields. The sowing takes place only a month later, by when the glaciers start melting and feeding the stream for subsequent irrigation. The main appeal of the artificial glaciers is that it provides water during the early spring for the crucial pre sow watering of fields when the glaciers that have receded in the wake of global warming haven't started to melt as yet and water from the springs are not adequate. If the farmers do not get irrigation water in time, sowing would be delayed and they consequently might have to harvest the crops prematurely.

3. Methodology for the Study

The study was conducted in three of the six villages in Leh district where artificial glaciers have been built by GERES partner, Leh Nutrition Project (LNP), over the last 10 years. The villages, Sabu, Nang and Shara, are located at different distances from the district headquarters along the highway to Changthang. All villages are south facing that have seen accentuated receding of their glaciers in the last two decades. Survey schedules were administered on sampled households within each village representing over 10% of the total households in the surveyed villages. The sample was stratified across hamlets and land holdings so as to ensure representation of families with fields in both upstream and downstream locations as also people from different socio-economic backgrounds that could possibly be benefiting differently from the artificial glaciers. A group discussion was also held in each village to delve into the issues emerging from the household surveys. Discussions were also held with LNP staff involved in implementing the projects on ground. The study was essentially qualitative relying largely on people's memory and their own assessments rather than on baseline and post project data or other quantitative measurements.

Of the 501 households across the three sampled villages, 54 were interviewed.

	Sabu	Shara	Nang	Total
Total Households	258	173	70	501
Surveyed Households	29	15	10	54
Average family size	6.2	5.9	5.6	6
Average Age of respondents	62.7	49.3	47.7	56.2

4. Reasons for Success and Failure of Artificial Glaciers

For a relatively simple and straightforward initiative such as building Artificial Glaciers in a village that brings with it clear positive impacts and one from which the whole village stand to benefit without raising issues of social dynamics around usufruct rights, one might assume there would be little that could come in the way of making the project a success. However, there clearly are social and physical features in a village that could help or hinder the successful implementation of a project. In

this case, following are some of the main characteristics of a village that, from the author's observations and perspective, could either help or hinder.

- People's involvement

The centrality of people's involvement and ownership of the process and product of grassroots development interventions affecting their lives can hardly be over stressed. People's participation in the decision making processes of artificial glaciers, prima facie appears, to be one of its weakest links. A technological solution to a community's problems, no matter how effective and well intentioned, especially one involving the use and collective management of a community resource, is unlikely to be successful and sustainable unless the people are totally informed and supportive of the intervention.

In many villages it is seen that people who have not been informed or associated with the project have developed a negative view towards not only the implementing agency but even the artificial glaciers in themselves. As an extension of their experience with many Government schemes, they start seeing this as the kind of work that stand to benefit the implementers more (through kickbacks) than the intended beneficiaries. This feeling comes especially when the construction related work is outsourced to a contractor rather than done involving the entire village community. The process of contracting out the work in most cases might actually be more 'resource-efficient' than by involving the entire village community. But, much more than what is gained in terms of saving some money and time is lost in disassociating the people from the process. It was seen that the ownership of the artificial glaciers do not set in well till the people are involved in the process of planning and implementing it. In the absence of a community ownership of a resource, the responsibility of managing it is essentially lost as well.

- Clarity of roles and responsibilities

Besides ensuring that the whole village or the concerned user groups are aware of the project and participate in the planning as well as implementing the project, it is very important to lay out clearly in front of them the roles and responsibilities of both the implementing organization and the village community who would benefit from the project. While the agency ensures funds for the project and takes overall responsibility of managing the constructions, the village community needs to fix an institution that would own and manage the artificial glaciers once it is ready to use. In most villages it could be the elected Panchayats that take up this responsibility. A clear mechanism of how annual monitoring and if need be repair and maintenance of the artificial glaciers also need to be worked out and agreed upon at the beginning of the project itself. It would be highly recommended that a small part of the project costs (5 or 10%) be borne by the villagers as a mark of their interest in the project. The village community would also need to set up a system to ensure that annual maintenance, if needed, is carried out by them without the dependence on an external agency. They could choose between volunteering to work on the site by turns (where each family sends a person for a day or two) or collect the money from every family to pay up for labourers to do the same.

- Realistic expectations

Experience shows that at times well intentioned initiatives can fail or suffer irreparable damage because of an 'over sell' of the project outcomes at the beginning. This is particularly applicable to projects that call for people's ownership and management of a common property resource, such as artificial glaciers. If the project implementing agency promises larger benefits, e.g. more water or more timely water in our case, then they eventually end up getting, there could be a corresponding dip in the people's enthusiasm in the project, which would tell on their involvement in managing the resource as a community. It is thus extremely important to share all aspects of the project transparently, including the best and worst case scenarios of the water discharge and timing from the artificial glaciers and how they are intrinsically linked to the climate variables in a given year. If people show enthusiasm after thoroughly understanding how the benefits might pan out, the chances are more that they will remain involved with the project even in a bad year.

- Site selection

Selection of a very appropriate site is the one of the most crucial factors determining how successful the artificial glacier is in catering to the needs of the people. A good site would be situated at just the right altitude ensuring the stored ice melts at just the right time. If it is located too high, the ice would melt later than when the people need it and if it is located too low, it would melt earlier than they could use it. The site should have a slow gradient so that the water runs slow and gets time to freeze as also a wide expanse ensuring more storage of water without having to build very high retention walls and risking their collapse. The site also needs to be largely in the shadow facing north to ensure the ice remains frozen during the winters and melts only towards early spring when time for the pre-sow irrigation nears.

- Using techniques requiring minimal maintenance

There are two major ways in which an artificial glacier is built. If the main water stream is not directly in the face of the sun during winters, an artificial glacier could be built by erecting walls in the stream itself at regular intervals. In case the stream doesn't get enough shade, water is diverted from the main stream to an adjoining valley that remains largely in the shade allowing the water to freeze within the walls built in that valley. The former technique, besides being economical, is also very low on maintenance unlike the later one that requires a lot of work during the winters in ensuring a steady flow of water in the diversion channel, keeping it clear of sand and soil deposits and in making sure thin sheets of ice are formed over the valley at regular intervals. The second technique thus calls for maintenance of the facility on a regular basis by the people themselves, which, especially if the village is not an organized community around maintaining common property, could be a challenge. Other variables remaining constant, the technique with a less intensive regular maintenance requirement always has a better chance of withstanding the test of time.

- A good water management system ensuring equal access to all

Unlike the rest of the country, where agriculture is largely rain-fed, being in the rain-shadow of the Himalayas bereft Ladakh of any agriculturally useful rains. The fields here are all irrigated, mostly by the tributary streams of the major rivers that bring down precious snow melt down from the glaciers. Owing to the preciousness of the stream and natural springs,

Ladakhi farming communities, centuries ago, devised ways of ensuring an equitable distribution of this resource amongst all. The institution of Churpon, the water manager, is among the most important in the village, as he is tasked with ensuring equitable access to irrigation water across the village.

Owing to changes that have come with modernization, village institutions have also seen a weakening of the sanctity/power they used to hold. While in many villages the *churpon*, selected on a rotation basis from all families, is still doing a fine job of water distribution, in others it has fallen weak and there are often quarrels amongst neighbours about the timing and duration of one's turn for water. For a successful and sustainable use of the artificial glaciers, it is important that water distribution within the village is fair, else there would be conflict related to usufruct rights which would have a direct bearing on how people organize themselves around managing such a facility.

- Agriculture remains an important source of livelihood

Ladakh has already made the transition from being a subsistence agriculture based economy to one with diverse pillars supporting its economy. Employment with the Government, armed forces, tourism and trade has emerged as equally important sectors besides agriculture. Given the relative hardship of working in the fields and the paltry savings from the mainstay cereal crops as compared to working in any of the other sectors, people are moving away from agriculture. In a large no. of villages, especially ones closer to the town, it is the elderly couples from the previous generation who are keeping much of agriculture still alive. The younger generation may at best come back to the village for a few days during harvesting, which is also waning out as people are largely resorting to using paid labour for harvesting and such work. Owing to its peculiarity, ploughing, with a pair of Dzos (hybrid of Yaks and Cows), has remained the only farm activity that could not be outsourced to labourers from outside the region.

Given this situation of a waning interest in agriculture as a livelihood option, it would help in the long run sustainability of the project, especially when it comes to owning and managing the artificial glaciers, that the proposed village community has a serious dependency on farming as a source of livelihood. Cereal cropping need not necessarily be the mainstay, as many villagers are now shifting their energy into growing vegetables and planting trees. As long as the availability for irrigation water has a strong bearing on their livelihoods, people are more likely to organize around managing their artificial glaciers.

- Scope to expand cultivable land

It was seen during the study that a lot of people were not very aware of how much difference the artificial glaciers in their village have brought about to their farms. While many did notice and articulate the increased yields of cereals, vegetables and particularly potatoes or in some cases an extra harvest of fodder, there were those who did not particularly think of the early water available from the artificial glaciers as having a huge role in it. But in villages where people were constrained to leave some of the farms fallow because they wouldn't get enough water to irrigate all fields at the crucial pre-sowing period, people were more articulate about how artificial glaciers have helped them in increasing their land under cultivation by

reclaiming their fallows since they could form a more tangible direct connection between the extra water from the artificial glaciers and the extra patch of land cultivated. So, if the village under consideration for a new project faces a situation where more land could be brought under the plough if the weak link of pre-sow irrigation is addressed, chances are high that the people would be more enthused and hence be more involved in the project to make it a success.

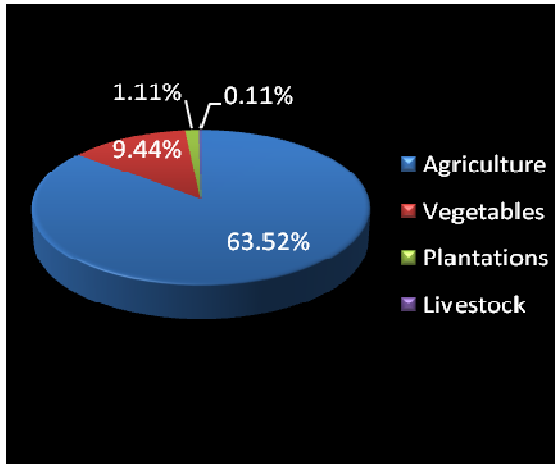
5. Cost-Benefit Analysis

As novel as a development initiative seeking to help poor and disadvantaged communities might be, the reality remains that development funds are very limited. A decision to propose or fund a particular initiative comes at the cost similar initiatives elsewhere or different initiatives with the same beneficiaries. Even though such decisions are very difficult to make, development agencies are increasingly faced with the situation of having to choose from a large number of ideas to develop or projects to support. It therefore becomes imperative that the benefits of potential projects outweigh the costs incurred to justify taking up a project in the first place, and that's where a cost-benefit analysis of the project comes in as a handy tool for decision making.

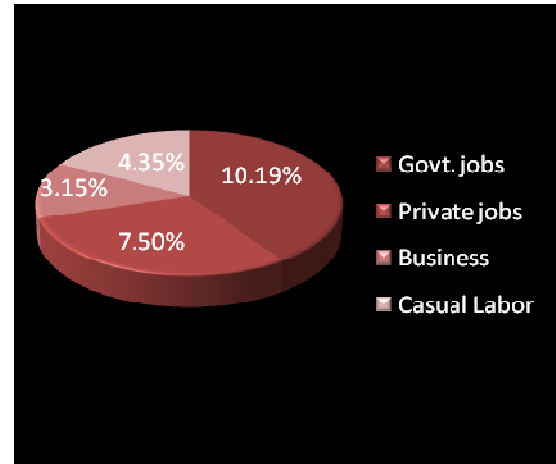
Social Cost Benefit Analysis (SCBA) is a contentious exercise though, as benefits accrued to the targeted populations and often ecosystem services that many projects provide are not very easy to quantify in monetary terms or require lengthy and cost intensive studies to do so. One of the villages in the study reported that before the artificial glaciers, people had to keep awake whole nights for their turn to irrigate the fields from the village stream and often tempers ran high and fights broke out between neighbours. After the artificial glaciers were built, there was enough water in the stream for everyone to get their turns during the day itself and nobody fights over water turns anymore. Now the question is how do we attach a price tag or run the economics of avoiding fights within the community and improving their collective social capital? In the case of another village, decreased snowfall and receding glaciers meant that the aquifers letting out through natural springs on which people were majorly dependent for drinking water as well as irrigating the fields did not get adequately recharged and water scarcity started to strain the life of a farmer. After a series of bunds were built on the stream as part of the artificial glacier project, the aquifers started to recharge better and the springs began to flow better. Calculating such benefits of the project become very difficult and they often do not get appropriately reflected in assessments of such projects.

It is also extremely important to understand the context fully to make a fair assessment of the impacts within the contextual realities rather than on a generalized plank. Despite the secondary and tertiary sectors in the region picking up as employment sources, farming (and in a few villages, pastoralism) still remains the main source of livelihood for most of the people. In the surveyed villages, people reported that 74.18% of their incomes came from farm based activities while 25.82% came from non-farm based occupations. The figures below show the detailed break-up of the various sources and it can be seen that agriculture make up for 63.52% of the average household income, followed by Government jobs at 10.19% and vegetable cultivation at 9.44%.

Average Family Incomes by source



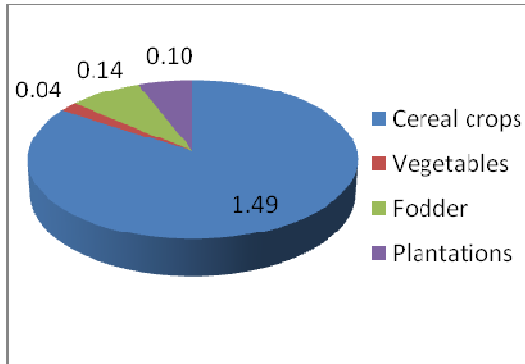
Farm based Income



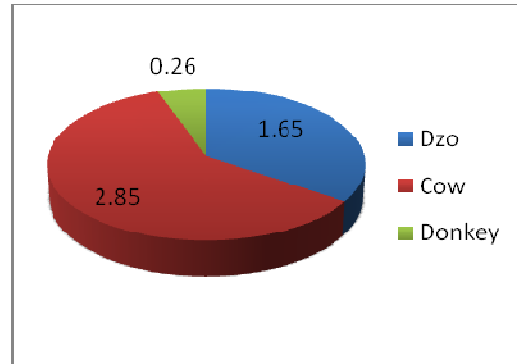
Non-farm based Income

It is interesting to note that this high dependence on farming is juxtaposed with the extreme ruggedness of the terrain where less than 0.25% of the total area is under cultivation. Being one of the highest, driest and coldest inhabited places on earth doesn't make agriculture an easy vocation to pursue. Yet, for centuries, people have inhabited this region and farmed in the most inhospitable circumstances, living a very frugal life and making optimum use of the very limited resources at hand. According to latest data published by the Government statistics and planning department, only 10,200 Hectares of land is under cultivation in Leh district. The average cultivable landholding for a family of five is thus around 0.7 hectares. If we discount for non-farming pastoral communities and the urban population, this might stand at around a hectare per farming family. Couple this with the fact that most families are able to get only a single crop of wheat or barley and that the average yield in most villages is not more than 3 to 5 times of what is sown, the farmer of Ladakh is actually fighting a lot of odds. In the surveyed villages, the average farm landholding was 1.77 hectares, slightly higher than the average for the district. Livestock rearing in these agricultural villages have gone down tremendously in the last 2-3 decades. Smaller animals like sheep and goat, that every family used to keep 20-50 of, have totally fallen out of favour while the cow and Dzo (Yak and cow hybrid) have managed to retain their place in the farmer's life.

Average Animal and Land holdings per family



Cultivated Land (Hectares)



Livestock

Note: People count Potatoes and Peas among main crops since they are planted on the regular fields in large quantities unlike the other vegetables that are planted in small plots of home gardens and green houses, or fodder crops that are generally planted on gravelly patches of land that are not fertile enough for regular crops.

The prime objective of building artificial glaciers is to make available water in the spring time for pre sowing irrigation. Lack of adequate water in the early season could mean a couple of things for the people. It could mean that they do not get enough water to cultivate all their land and have to leave some of the fields fallow, it could also mean that the sowing is delayed till the glaciers start melting to provide enough water for irrigation or it could mean that they get a lower yield from the crops than they would have otherwise got. So the benefits would majorly have to be weighed in terms of an increase in the crop yield and in the amount of land cultivated. A major limitation of the survey however has been that people were not able to provide us with the exact quantum of these benefits. Results of the study are thus more qualitative than quantitative in nature.

An overwhelming majority of 83.33% respondents feel that yield from cereal crops have increased after the water available from the artificial glaciers. If we break down the respondents in terms of landholdings, as shown in the table below, we see a clear pattern of the increase in yields reported corresponding to the land holdings, higher the land holding higher the observation of an increase in the yields. While there is no reason to believe that only the bigger farmers have actually got an increased crop yield, it might be that the increased yield translates into a lot more 'visible' extra harvest for the bigger farmers and hence gets noticed while the same for the smaller farmers is much modest and the change in yield is not felt or articulated as significant by many. A significant 23.53% of the families also report an increase in their cultivated land following the extra water available from the artificial glacier (AG).

Land holdings (Hectares)	< .5	.5 - 1	1 - 2	2 - 3	> 3
% families	7.4	11.1	57.4	18.5	5.6
Average cultivated land	0.3	0.7	1.3	2.4	3.9
% families to report increase in cultivated land after AG	33	66	16	10	33
% families to report increase in crop yield after AG	50	83	88	90	100

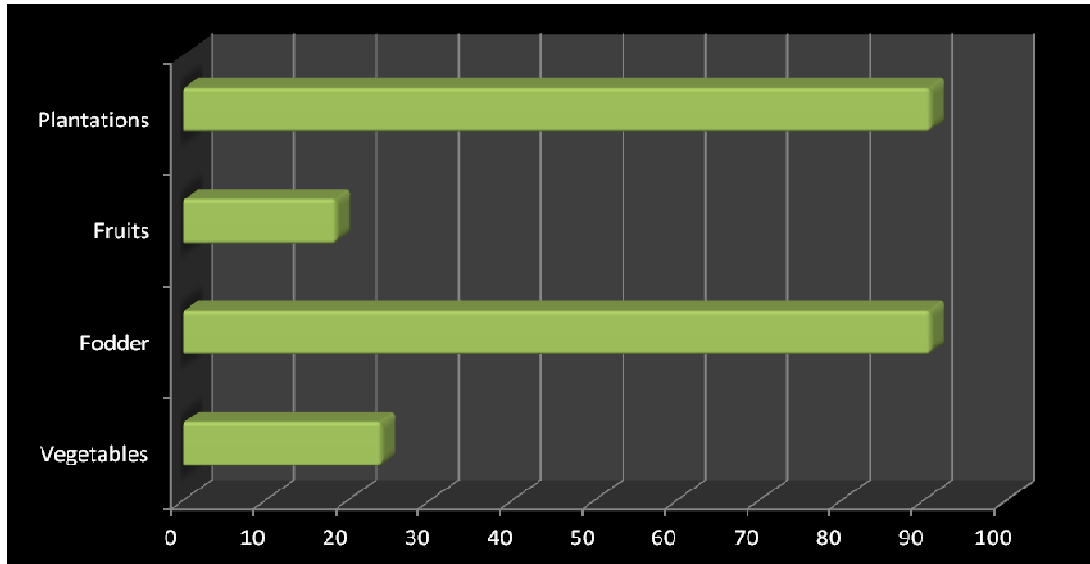
[Percentage families reporting increase in yield and cultivated land across land-holdings](#)

It was interesting to note that all cases of expansion of cultivated land were reported from Shara village. The village faced a very severe water shortage for the pre sow irrigation before the artificial glaciers. Water turns would run through the whole night as well and people would keep awake half the nights to water their fields from the trickle that was available in the streams at that time. Tempers would often run high during such times and people got into heated arguments with their neighbours over one's turn for the water. Things changed after the artificial glaciers were built. The trickle in the stream was consolidated by the ice melt from the artificial glaciers and the flow was enough to water the fields quicker and everyone got their turn during the day itself. The village has a rule that the first right on the water is of the cereal crops, so until the cereal crop fields of the entire village get water, no other field including fodder, vegetables and plantations could get any water. After the renewed water supply through the artificial glaciers, many started cultivating the land they had left fallow and even brought cultivable waste under irrigation, especially for fodder, potatoes and plantations.

The case of Shara village also drives the point that if we select villages that have a scope of expanding land under cultivation, they would do so when additional water makes it possible, further ensuring people's interest and involvement and at the same time increasing the scope and impact of the project. Sabu village, being very close to the town, have always had an impetus on growing cash crops. They grow all sorts of vegetables but their potatoes are particularly in demand as they are considered of the best quality. Potato yields in Sabu are also the best in the whole region, giving them all the more reason to focus on growing potatoes. The availability of early water from the artificial glaciers has particularly helped the people in growing more potatoes, an important source of income for a large number of families in the village. Same is the case with Nang village which has shifted in a major way from focusing on wheat and barley to potatoes and peas, especially potatoes, in the last 10-12 years and particularly so in the last five years. The artificial glacier in the village was built five years back, and one could see a direct relation between growth of cash crops and the water needs being eased out by the artificial glaciers.

As could be seen from the chart below, besides cereal crops, yield from fodder and plantations have also increased substantially after the artificial glaciers. Fodder, potatoes and peas are particularly responsive to the amount of irrigation it receives. In some villages fodder could be harvested more

than once if it gets adequate water. Potatoes and Peas account for most of the increased yield of vegetables shown below.



Percentage families reporting increase in yield of non-cereal crops after Artificial Glaciers

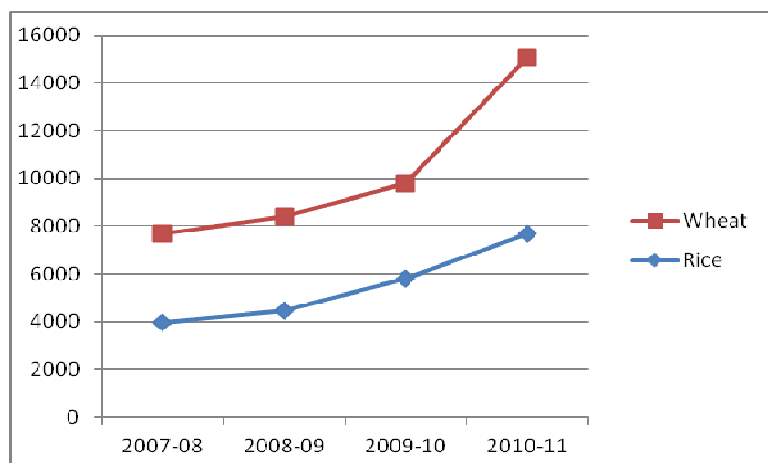
In all the three villages studied, people have overwhelmingly expressed the benefits from the artificial glaciers and the few who were not so sure about it, village leaders feel, were because they haven't seen for themselves how the water melt from the artificial glaciers feed the stream. Since the water from the artificial glaciers feed into the main stream that in the winter is fed by perennial natural springs, people often don't realize that much of the water in the main stream, during early spring, actually comes from the artificial glaciers. The disturbed weather patterns add to this confusion since the amount of snowfall received during the winters and the onset of summer have both become very variable and as a result a particular year might bring more than ample water and the next year there might be a drought like situation. In the absence of a fixed trend, people are generally unable to evaluate the amount of water they are getting from the artificial glaciers.

GERES studied the water discharge from the artificial glacier in Nang (the only systemic study thus far) using a hydrometer and automated data logger over the 2011-12 winter. The data reveals that the mean discharge of the main stream during the winter was around 8,000m³/day. The mean discharge from the artificial glaciers, for around two months of the early summer that it is feeding water back into the main stream is around 130m³/day, accounting for around 20-25% of the overall stream water (the mean average is 16%, but during the early summer, discharge in the main stream is at its lowest compared to early winter when it is at its peak). At 130m³, the artificial glacier is contributing to the irrigation of around 0.7 hectares or 14 Kanals of land per day, taking 75m³ water per hectare of land as per LNP assessments. Over a period of two months that translates into 42 hectares or 820 kanals of cultivated land, enough to water the farms in the entire village more than once. In Sabu and Shara, where they have built several artificial glaciers, the contribution of the artificial glacier is likely to be much more.

The acknowledged impact of the artificial glaciers also seems to suffer from the 'iceberg effect'. Just as only a small part of the iceberg is above the water and visible to the eye, only the most obvious

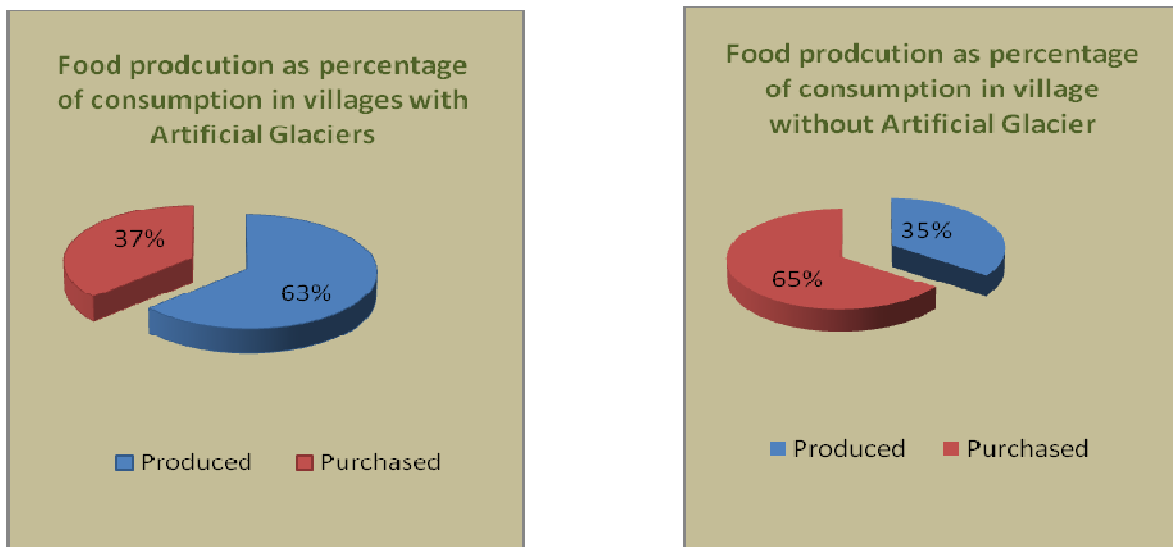
impacts of the artificial glaciers i.e. increase in cultivated area and crop yields, are seen and articulated. Non-monetary/quantifiable benefits often go unnoticed just like bulk of the iceberg under the water not visible to the human eye. End to water quarrels and improving social capital, as mentioned above in the case of Shara village is a case in point. Similarly, in Sabu village, the thinning water from the natural springs, on which the village is dependent not only for drinking water but also largely for irrigation, got a flip-up after the aquifers got recharged better because of the stored water in the artificial glaciers percolating in the ground. The area around the artificial glaciers also developed into a lush pasture where people are sending their animals to graze. Another observation, comparing data from these villages with that of a similar agricultural village studied for the impact of climate change, even though it would need corroboration through a more focused and detailed study, could point to a very important contribution of the artificial glaciers, that of keeping agriculture alive in a region that is fast moving away from it and consequently reducing food insecurity of the local population.

Ladakh was a primarily subsistence agriculture based society till a decade or two back. In this period, people have started to move away from agriculture preferring work in the other sectors of the economy. Agriculture has come to be seen as very laborious and unprofitable compared to salaried jobs and even petty business. On top of that, rice and wheat flour, procured from the Indian plains by the government’s Public Distribution System (PDS) and made available to the people on subsidized rates, has had the unintended impact of dis-incentivizing farming. Purchasing cereal crops from the PDS work out cheaper than growing one’s own. If it was not for the hay from the wheat and barley plants that people need to feed their animals, and also fetch more money in the market than the grains, a very large number of people may not actually be farming any more. In a region that has access to rest of the world through land for less than half the year, a heavy reliance on staple food transported from outside the region, through highways that could come under fire from not-so-friendly neighbours, as happened in 1998, raises important questions of food security. Latest data available from the Food and Civil Supplies Department, as could be seen from the table below, show that procurement and distribution of the staple wheat flour and rice have gone up by 98% and 95% respectively in just the last three years, indicating a growing trend of people buying more food than they are growing.



Staples supplied in the district through the PDS (metric tonnes)

A comparison between the villages with artificial glaciers studied and a similar sized primarily agriculture village without an artificial glacier (Shakar village, surveyed by the author for a study on climate change vulnerabilities) show that the people in the former are still growing bulk of their staple food in comparison to the later. As shown in the graph below, the project villages grew 63% of their food and procured 37% from the PDS. It was almost the reverse in case of the other village, where only 35% of the food was grown and 65% was procured from the PDS. It is not suggested that the villages under comparison are representative of the two sets and it would also be farfetched to propose artificial glaciers as the only differentiating variable explaining the particular difference between the two sets, but an inference could still be drawn.



6. Methodology for People's Participation

As delved in detail earlier in the report, ensuring people's participation in a project such as building artificial glaciers, that puts in place a new common property resource from which the entire village stands to benefit and one that calls for community ownership as well as the responsibility of managing and maintaining the resource, is of utmost importance. One of the crucial shortcomings observed in the currently running projects was that by and large a technocratic approach to solving a prevailing problem was followed where the people's involvement in planning and implementing the solution did not seem to have been treated as central. To be fair on the implementing agency, making sure the whole village participates in an initiative where the results are not necessarily immediate or even very visible, is not an easy task, especially if the village is big and spread out.

The new window of opportunity here is the newly elected decentralized institutions of governance, the Panchayats. Much of the projects were carried out when these institutions did not exist, leaving a vacuum in terms of an organized and elected village institution to deal with. Mobilising the entire village community and fixing responsibility in terms of ownership and maintenance were not easy and the project managers often found it more efficient use of their time and money to keep the people's mobilization to a minimum and also contract out the physical building of the structures to petty contractors from within the village.

Now that the Panchayats are in place in every village with a panel of elected representatives, the project implementing agencies have a ready institution to deal with. What one needs to do now is to involve them in the project from the very beginning, at the conceptual level. One needs to lay out all aspects of the project in front of them in terms of what issue the project seeks to redress, how it would be carried out, what are the likely benefits and risks, a clear understanding of the roles of the implementing agency, the entire community and the Panchayat. A possible contribution to the project from the beneficiaries should also be discussed at this stage. People's involvement in carrying out the physical works as also the Panchayat's role in managing the resource afterwards should be discussed in detail. It might also be a good idea to put everything in writing and get an MoU signed between the implementing agency and the Panchayat. The Panchayat representatives as also knowledgeable people from the village should be consulted in selecting an appropriate site for the artificial glaciers.

Besides the representatives, regular meetings with the entire village community also needs to be organized at crucial stages of the project, most importantly at the beginning to explain the entire details of the project to the whole village so that everyone stands to understand what is promised and how their participation is expected in the project. This would dispel the likely spreading of rumours about the project in the absence of first hand information that often leads to people harbouring ill will or even turning against the agency, their own representatives or the project in itself.

7. Limitations of Study

The study was largely based on a survey of 3 of the 6 villages where GERES partner LNP had built artificial glaciers. Most of the glaciers were built 5 to 10 years back and no baseline studies had been conducted in any of these villages, making it very difficult to do a scientific assessment of the project impacts. The study also relies heavily on people's accounts of increase in cultivated land and yield without a scientific assessment of the degrees of these changes as could have been done using field data collected before and after building the artificial glaciers. Data on volume of water in the artificial glaciers and their flow during early summer and its comparison to the flow in the regular stream are also not available that could have aided quantification of the benefits. GERES' data from Nang village did give a peak into that aspect but since the data collection was done for just a single winter, given the huge variations in temperature and precipitation in the region it cannot be taken as representative for a typical year.

The other limitation of the study is that we are unable to quantify the amount of aquifer and ground water recharge that could be attributed to the artificial glaciers. People have clearly seen the difference in the quantum of water available from the natural springs before and after the artificial glaciers were built, but it would take data collected for multiple years before and after the artificial glaciers to prove the difference, to quantify it and then to monetarise it. Similarly, the improved social capital following cessation of water disputes in the village after the artificial glaciers is an indirect benefit that could not be quantified, and yet remains of unquestionable value.

8. Conclusions

In the absence of a rigorous study backed by data collected from both before and after implementation of the action, it is difficult to quantify the benefits that could be compared with the costs of the project. However, from all the accounts of direct and indirect benefits presented in the report and looking at them within the prevalent context, the cost of three to seven Lakh Rupees (5.000 to 10.000 Euros) that is typically incurred on an artificial glacier seems to be well justified by the collective services it renders.

The reliable and timely water for pre sow irrigation not only give an impetus to improve farm based income for the villagers, but, in the times of climate change, an unreliable weather, receding glaciers and dwindling water resources, as also a times when people are leaving the agriculture sector in droves for 'greener pastures', artificial glaciers, in a small way, is helping keep people's faith alive in the farm.

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