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Stimulating smallholder dairy market and livestock feed improvements through local innovation platforms in the Himalayan foothills of India

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ABSTRACT

Innovation platforms (IP) are increasingly used in agricultural development to address complex issues which require diverse actors to work jointly to identify constraints and implement solutions. Documenting outcomes associated with the use of IPs and identifying factors linked to positive results are important if performance is to be optimized. This study investigates changes in smallholder dairy production and marketing associated with the establishment of a series of innovation platforms in Uttarakhand, Northern Himalayan region, India. We studied the links between innovation platform processes and outcomes using systematic documentation of meetings and interventions along with a post-intervention assessment which compared households from villages with and without the innovation platform intervention. We found that households participating in IPs showed increased dairy milk sales, increased income and improved breeding and feeding practices. Factors associated with these outcomes were the process of issue identification, the diversity of actors participating in meetings and the quality of follow-up on the agreed action plans.

1. Introduction

India is the largest milk producer in the world with an 18% share of world milk production and milk production has been growing at an annual rate of 4.2% for the last 2 decades (USDA, 2017). Global demand for animal based calories including meat, dairy based products and eggs is projected to double from 2010 to 2050 especially in developing countries due to increased population, income growth and urbanization (Gouel and Guimbard, 2019); demand for dairy products in India has already increased significantly among rural and urban populations (Ohlan, 2016a). Though the share of agriculture in GDP is declining, the contribution of livestock to agricultural GDP in India has increased from 20% in 1988–89 to 26% in 2015–16 of which 70% comes from the dairy sector (NDDB, 2016). Based on these emerging opportunities in the dairy sector, there is considerable scope for the poorest sectors of the population to enhance their livelihood, since 80% of dairy animals in India are owned by households with less than 2 ha of land (NSSO, 2013). Dairying is the major source of rural employment especially for women. Income from dairying has an equalizing effect on the distribution of income for all categories of farm households compared to the distribution of income arising from crop production (Mandal et al., 2010; Squicciarini et al., 2017). Growth in the Indian dairy sector dates to the successes of the Operation Flood program in the 1970s. Various non-governmental organizations and the National Dairy Development Board were instrumental in promoting institutional and technical interventions to improve the efficiency of dairy marketing and to increase availability of artificial insemination and extension services. However, dairy sector growth is not equally distributed across different states (Ohlan, 2016a). Uttar Pradesh, Rajasthan, Punjab, Maharashtra and Andhra Pradesh are the top 5 states accounting for more than half of the milk production in India. Eastern and hilly states are minor contributors to the dairy sector.

Uttarakhand is one such hilly state with slow dairy growth of around 3% through the 2000s (Ohlan, 2016b). Most of the dairy animals in this state are kept on mixed crop-livestock farms. Dairying is the most important livelihood source after arable agriculture and remittances from outmigration with nearly every household owning one or two dairy animals (Joshi, 2019). The outmigration of men due to uncertainties in hill-land agriculture (Mamgain and Reddy, 2016) has led to most dairy activities being carried out by women in this region (Bhoj et al., 2014), despite their already considerable work-load (Rachit et al., 2009). There are two major constraints to increasing dairy

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growth in this region: market access and low productivity in dairy production.

Challenging road infrastructure negatively influences the participation of dairy farmers in the market (Bardhan et al., 2012). 39% of villages are not directly connected to roads and people have to walk 3–5 km over challenging terrain to reach a metaled road (Mehta, 1999). The para-statal Uttarakhand Cooperative Dairy Society, also known by its brand-name Aanchal, is the only major formal milk marketing channel in this region, despite its limited productivity and inactive status in many villages (Sati and Panwar, 2017). In Uttarakhand, dairy cooperatives were established in the 1990s by the State, based on the success of the Operation Flood programme in Gujarat, to promote farmers' access to dairy retail markets. In addition, various technological interventions were introduced to enhance the productivity of dairy production, including improved breeds of dairy cattle, partly through artificial insemination, animal health interventions such as vaccination and deworming, as well as improved forages and concentrate feeding. Despite the potential of these technological measures, their adoption has been very low in Uttarakhand (Rathod and Chander, 2016), especially in the hilly districts of the state.

Livestock feed scarcity is a common and fundamental constraint in many Low and Middle Income Countries and frequent attempts have been made to promote various feed innovations such as food-feed crops, fodder trees, improved grasses and legumes (Thornton, 2010). However, the adoption of these technologies has generally been limited. Various reasons for this have been reported, including limited access to markets and extension services, lack of credit for investment in feed technologies and lack of basic knowledge on feed management (Franzel et al., 2014; Kumar et al., 2015; Suman et al., 2017; Sumberg, 2004). However, the "technology push" approaches which have often been employed generally disregard indigenous sources of knowledge and fail to take account of farmer perspectives (Lundvall et al., 2002; World Bank, 2007).

Some have argued that feed scarcity has less to do with information and technological scarcity than with challenges at the level of the innovation system which hamper the capacity of the system to innovate (Hall et al., 2007; Kebebe et al., 2015). Feed is an intermediate product in the livestock value chain, the final product being milk or meat. Incentives to invest in new feed options are often lacking in the absence of a ready market for livestock products. Improving feed options can be complex and may require the involvement of many actors including feed suppliers, extension services, seed producers and so on. Bringing all these actors together to, firstly, improve market arrangements for milk and secondly, improve feeding practices to allow for higher milk yields can be challenging. Innovation capacity development can be addressed through development approaches which acknowledge the wider agriculture innovation system (AIS) where innovation is seen as emerging from a network of public and private organisations, enterprises, and individuals whose interactions produce, diffuse and utilize knowledge which brings economic and social benefits (Lundvall et al., 2002; Spielman et al., 2008; World Bank, 2007).

One means of building this "capacity to innovate" is through the establishment of connections between key actors in a network to facilitate dialogue and change. Approaches to building such connections and networks include innovation platforms (IP) (Ayele et al., 2012; Homann-Kee Tui et al., 2013; Kilelu et al., 2013), public–private partnerships (Nissen et al., 2014), multi-stakeholder platforms or collaborations (Reypens et al., 2016; Warner, 2006), or value chain collaborations (Ros-Tonen et al., 2015). An innovation platform can take various guises but in the context of the current study we are drawn to the definition of an innovation platform developed by researchers from across the CGIAR and beyond as "a space for joint learning and change. An IP is a group of individuals (who often represent organisations) with different backgrounds and interests: farmers, traders, food processors, researchers, government officials, etc. The members come together to diagnose problems, identify opportunities and find ways to achieve their goals. They may design and implement activities as a platform, or coordinate activities by individual members" (Homann-Kee Tui et al., 2013). Innovation platforms can build the capacity of their members to communicate and innovate and enable them to cope with changing conditions (Boogaard et al., 2013). Some of the key aspects of innovation capacity are self-organisation to work together, building new skills, adapting to new challenges, creating new ideas, listening to other ideas and capitalizing on emerging opportunities.

IP approaches are gaining prominence in agricultural development practice and have been used to deal with a range of issues including natural resource management, poverty alleviation, value chain development and food security at various levels (e.g. Duncan et al., 2015; Pali and Swaans, 2013; Swaans et al., 2013). Because innovation platforms do not require any formalised participation of public or private institutions, are focused on stimulating innovation and can consider both production and market aspects, the approach seemed appropriate to address market and productivity issues in Uttarakhand's dairy sector in the research for development project investigated by this study.

There have been many qualitative case studies aiming to evaluate the impact of innovation platforms. These studies indicate that innovation platforms can successfully facilitate institutional change (Hall et al., 2003; Nederlof and Mariana, 2011), strengthen market relationships (Davies et al., 2017; Sparrow and Traoré, 2017), increase capacity for collective action (Davies et al., 2017) and promote technology adoption (Pamuk et al., 2014). However, many of these studies have focused on limited elements of the approach; either on the impact side or aspects of IP facilitation and few if any have systematically investigated how the use of IPs is associated with institutional and technical innovation and crucially with developments in productivity and ultimately household income. We hypothesise that the outcomes associated with IPs depend to a considerable extent on the processes involved in their management. Positive outcomes can be achieved from innovation platforms through various measures which include negotiation, provision of resources or information, research, lobbying and advocacy (Duncan et al., 2013). The resulting impacts can be diverse; some may be measurable, such as increased income and adoption of technologies, while some may be hard to measure, such as increased innovation capacity, increased communication and improved collaboration. In this study, we set out to investigate the links between the convening of IPs and stakeholder behavioural outcomes as well as changes in dairy productivity and household income. We focused on two main classes of behavioural innovation: first, we were interested in how IPs might be associated with "organisational innovation" by which we mean institutional change including adjustments to, for example, market arrangements, credit facilities, and feed supply arrangements. Second, we were interested in how convening of IPs might be accompanied by increased technical innovation, for example development and adoption of new livestock feed and breed technologies which would then result in productivity and income increases. As well as these end points, we studied the processes within the IPs to better understand how the effectiveness of IPs might be improved. The objective of this study was therefore to document the outcomes that accompanied the establishment and ongoing facilitation of local innovation platforms at household and value chain level and the processes involved in managing IPs that were associated with these outcomes. The research questions we set out to address were:

1. Are IPs associated with organisational change, adoption of technologies and increased dairy productivity?
2. What are the key processes in establishing and facilitating IPs that seem to contribute to positive outcomes?

2. Methodology

The "MilkIT[1]" project was a research for development project funded by the International Fund for Agricultural Development (IFAD) between Nov 2011 and Dec 2014. The aim of the project was to *contribute to improved dairy supported livelihoods in India and Tanzania through intensification of small holder production focusing on feed enhancement through the value chain and innovation approaches*. In India, the project was implemented in the hill state of Uttarakhand and managed by the International Livestock Research Institute (ILRI) with implementation by two NGOs, namely the Institute of Himalayan Environment Research and Education (INHERE) and the Central Himalayan Rural Action Group (CHIRAG). Selection of sites was designed to align with implementation districts of the Integrated Livelihood Support Programme (ILSP), a large IFAD loan programme which was starting at the same time as MilkIT. Of the long list of districts selected for ILSP, Almora and Bageshwar districts were selected for MilkIT, based on the extent of dairy activity and the experience and local integration of potential implementation partners.

2.1. Description of study sites

The study sites of Almora and Bageshwar districts are in the Kumaon division of eastern Uttarakhand with an average altitude of 1600 and 1000 m above sea level respectively, a dry period from March to June (summer), a rainy season from July to September (kharif) and winter season from October to February (rabi). The average annual rainfall in these districts is 1014 mm in Almora and 1331 mm in Bageshwar. Forest cover accounts for 73% of land, of which 30% is maintained by local communities through a system known as Van Panchayat.[2] Fodder collected from these community forests, such as hay and tree leaves is the main source of feed for livestock in this hilly region. Both districts have some arable land (10–20%) and small areas of grass land (< 5%) (Sati, 2016).

Agriculture is the main form of livelihood in this hilly region which is dominated by subsistence cereal farming with low productivity (Sati, 2005). Outmigration of men to nearby cities is very common to support family expenses (Mamgain and Reddy, 2016). The dairy sector in these districts is of considerable importance because there are few other livelihood options for rural households. Cattle constitute the major share of the livestock population in the state (44.6%) and milk accounts for about 77% of total output value from the livestock sector, despite being focused on home consumption. Hardy local livestock breeds dominate the cattle population, with very low adoption of crossbred cattle. In Almora, only 4.3% of the cattle population is crossbred while in Bageshwar the figure is 0.5% (Patoo et al., 2011). Many of the villages in these districts are far from paved roads making it difficult to access markets for selling milk. This has led to the formal urban markets being captured by private traders from plain areas. However, in recent years improved infrastructure, especially better road connectivity, has created opportunities for farmers to link to larger markets and has thus provided the potential to generate increased income from dairy farming (Sharma et al., 2007).

2.2. Establishment of IPs

In each district, one block[3] was selected for project interventions, based on the extent of dairy production and marketing as well as of established development institutions for project implementation. Sult block was selected in Almora, and Bageshwar block in Bageshwar district. Within these blocks, a list of administrative village units was established, where field activities could potentially be implemented. These lists comprised 42 "revenue villages" in Sult and 39 "revenue villages" in Bageshwar. However, these administrative units do not represent actual settlement patterns in this area because farm households are dispersed, within small settlements and are therefore not an ideal unit for selecting participants for group activities. A village census was conducted to determine actual settlements in the selected areas. Subsequently, a geographical village clustering approach was followed to select intervention sites for IP establishment and their non-intervention counterparts. Although villages and settlements are typical units for identifying activity areas in development projects, innovation platforms require larger units, especially where value chain development is concerned. Therefore, "village clusters" were used as the unit of activity for the innovation platforms. The settlements recorded in the village census were grouped (where appropriate) into mini-clusters, representing 2–4 neighbouring settlements which could easily collaborate, and which are from here on referred to as villages. Where possible, these villages were then grouped into village clusters, with 2–4 neighbouring villages forming one village cluster, representing a suitable activity area for a field facilitator and a sufficient number of households on which to base a livestock feed innovation platform. Accordingly, 5 village clusters were defined in Sult block and 7 village clusters in Bageshwar block. These clusters were characterised by road accessibility, number of dairy animals, presence of self-help groups, interest among local farmers in marketing milk and the availability of feed for targeting project interventions.

Out of the identified clusters, four village clusters were selected in each block in collaboration with the implementation partners; two were designated for IP activities (one with good road access and one with medium road access) and two with similar characteristics as non-intervention sites for comparison purposes. The total number of households represented in these selected village clusters was 1731 from 17 villages. Feed IPs were established in each of the two village clusters selected for IP interventions in each block, resulting in four Feed IP's in total. A Milk Marketing IP was also formed in each block with contributions from the two Feed IPs formed in that block (Table 1). Feed IPs were smaller units than Milk Marketing IPs because they were designed to specifically focus on local feed related activities. The Milk Marketing IPs needed to cover a larger number of producers to make them attractive to milk value chain actors and because milk market issues tend to be at larger geographic scales. The members from Feed IPs were also part of the Milk Marketing IPs. The IP village clusters, and their non-IP counterparts were in close proximity as depicted in Fig. 1. An inventory mapping exercise was undertaken to identify the stakeholders involved in the dairy value chain in these two districts to ensure their inclusion in IP meetings and further activities. These stakeholders included milk market actors, feed sellers, NGOs, animal husbandry departments, rural development banks, private financial institutions, agriculture departments, forest departments and other service providers. Dairy producers were represented in the IPs by farmers nominated through local self-help groups (SHG). Different producers were involved in each meeting although some key people participated many times. After each meeting, participants shared the agreed action plan with other dairy producers at the village level through SHG meetings. Dairy stakeholders, other than dairy producers, participated in either feed or milk marketing platforms based on their areas of expertise and their activities. Some stakeholders, for example development organisations such as NGOs and animal husbandry departments, participated in both types of IP.

The main development intervention in this project was the application of the IP approach which included the regular convening of IP meetings and the implementation of follow up interventions as agreed in the IP meetings. Stakeholders were invited to attend IP meetings to discuss various ways to enhance dairy production. This approach aimed at identifying innovations which would enhance dairy production

[1] Full title: Enhancing Dairy-based Livelihoods in India and the United Republic of Tanzania through Feed Innovation and Value Chain Development Approaches (MilkIT)

[2] Van Panchayat forests were formed in early 20th century and allow the villagers to harvest important forest products like grass, tree leaves, leaf litter, timber and wood. They have a constitution which sets out operational rules for the use and management of forest products.

[3] Block is the subdivision of a district for administrative and development purposes.

Table 1
Details of villages selected for Innovation Platform (IP) activities and their non-IP counterparts in the study area, Uttarakhand.

District	Block	Name of village cluster	IP established?	Villages	Households
Almora	Sult	Barkinda	Yes	2	222
		Saknara	Yes	2	309
		Gahnaheet	No	2	118
		Nailwalpali	No	3	94
Bageshwar	Bageshwar	Sainj	Yes	2	379
		Joshigoan	Yes	2	233
		Chouganchina	No	2	134
		Khabra	No	2	242

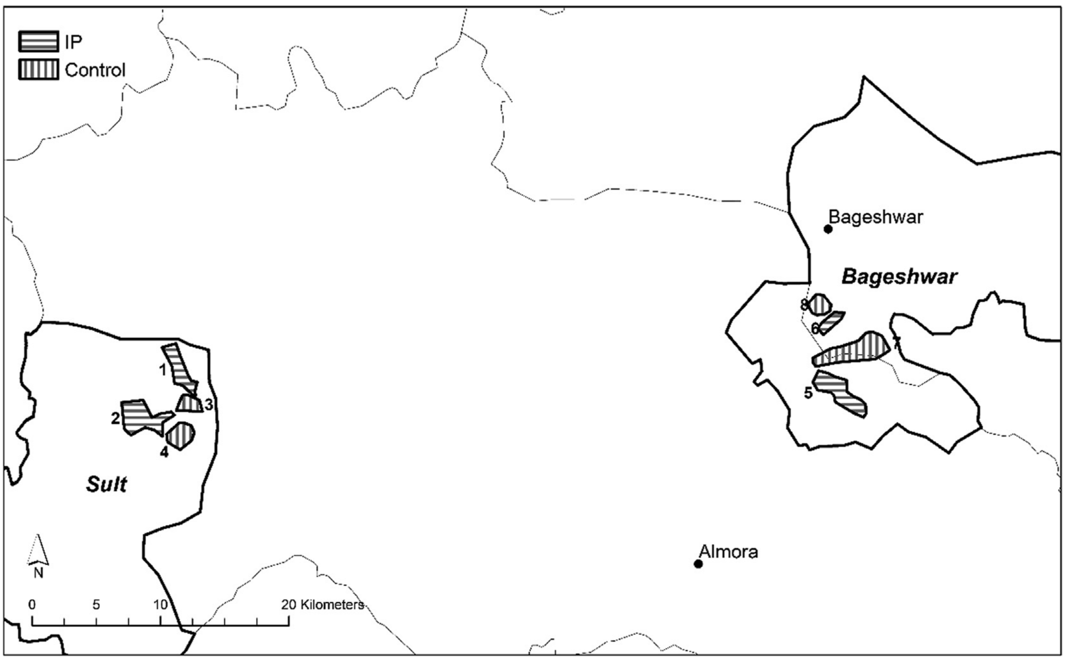

Fig. 1. MilkIT project village clusters, Uttarakhand (names of village clusters*: 1-Barkinda; 2-Saknara; 3-Gahnaheet; 4-Nailwalpali; 5-Sainj; 6-Joshigaon; 7-Chouganchina; 8-Khabra)*.

through both institutional and technological innovations. The main types of innovations associated with the introduction of innovation platforms were dairy market institutional arrangements and livestock feeding innovations. Households in the non-IP village clusters were not invited to IP meetings and did not receive any benefits from the IP approach except the standard government interventions which were similar in IP village clusters and in their non-IP counterparts.

2.3. IP study design

In this study, we investigated IPs as an intervention strategy at two levels:

1. IP functioning and process
2. Outputs and outcomes at value chain and household level associated with application of IPs

IP functioning and processes were evaluated based on key indicators developed by the project team including type and chronology of activities conducted, inclusiveness and diversity of members who participated, which issues were prioritized, qualitative organisational or technical changes over time and a log of follow-up actions. These indicators were assessed based on data collected at IP-meetings and through follow-up documentation.

Outcomes at household and value chain level were measured using indicators such as changes in marketing strategies, rate of adoption of technical innovations, increase in dairy productivity and changes in institutional engagement. These were collected through an endline survey as explained below.

2.3.1. IP-meeting and follow-up documentation

Three types of IP meetings were organized. Firstly, core meetings were scheduled every 3 months for both Milk Marketing and Feed IPs involving a wide range of stakeholders including producers and non-producers. Between these core meetings, follow-up meetings were held on an ad hoc basis in the villages as required. The third type of meeting was the individual meeting where MilkIT staff met with a specific individual or institution to follow up on the actions agreed in IP meetings. In addition to these meetings, exposure visits and trainings were organized based on needs emerging from the IP-meeting discussions. The agreed actions at the institutional level were followed up individually either by farmers, NGO staff or ILRI staff.

IP activities were summarized through systematic documentation after each IP meeting. Data were collected in four categories: meeting identification, details of issues discussed, researcher observations and participant details. Meeting identification included the type of meeting, the venue, who was invited to the meeting, who facilitated the meeting and the duration of the meeting. Details of issues discussed captured the topics addressed, agreed actions and who agreed to take responsibility for agreed actions. Based on this, the team captured the follow-up of agreed actions before the next meeting and updated IP participants at the beginning of the next meeting. Researcher observations documented the process followed, changes from the last meeting and what worked well in the meeting discussions. Finally, participant details captured the various characteristics of all participating actors, including gender and contact information. The IP progress document was updated after each meeting by the project team, and any changes in the village or at the institutional level were also captured and documented. The documentation was carried out from January 2013 to November 2014.

2.3.2. Baseline census and endline survey

Before the project interventions were initiated, two surveys were conducted. Firstly, a baseline census was implemented in all 1731 households of the IP and non-IP village clusters. This census collected data on dairy animal population, production details and marketing linkages. Secondly, focus group discussions were conducted through the use of the Feed Assessment Tool (FEAST) (Duncan et al., 2012) in 6 IP villages and 6 non-IP villages to collect data on existing feeding practices and availability of feed which helped to inform the strategies of the IPs.

At the end of the project, a post-intervention assessment survey was conducted in 192 households spread across 8 village clusters. Six settlements were selected randomly among each of the eight IP and non-IP village clusters. Four households were randomly selected from each selected settlement, with two females and two males acting as respondents. This post-intervention assessment survey was conducted from September to November 2014. The respondents were asked to respond on aspects of dairy production and income, livestock owned, feeding procedures, breeding and health management, market arrangements for selling milk as well as crop and fodder husbandry. Information on cropping patterns, income from dairy, improved feeding practices, breed management, marketing of milk and changes in the consumption patterns was collected based on recall for the previous 12 months. The respondents from the non-IP villages were also asked whether they had attended any of the IP-meetings conducted to assess any spill-over effects[4] of the innovation platform activities.

2.3.3. Data analysis

The IP-meeting and follow-up documentation was analysed by simple descriptive analysis to summarise the issues discussed, the diversity of actors participating, follow-up of the agreed actions and the timeline of interventions implemented.

For the assessment of productivity and livelihood benefits, households which had been included in both the baseline census and the post-intervention household survey were identified for further analysis to assess changes in key variables. Because only 2 village clusters were selected as IP and non-IP sites per block (Table 1), respectively, differences in farm and household characteristics between households in IP and non-IP village clusters existed before the convening of the first IP meetings. Therefore, the study focused on comparing changes over time between the IP group and the non-IP group, following a differences-in-differences approach. This follows the underlying assumption that IP and non-IP households would show the same rate of change following the intervention, irrespective of the base-line levels of the investigated characteristics. Accordingly, the interaction of the IP intervention and time was used to investigate the association of the IP intervention with changes in indicators in the statistical models.

The first statistical model considered milk yield as the response variable and time and IP intervention as the explanatory variable to test for productivity effects. The design factors 'district', 'village cluster' and 'settlement' were included, as they were assumed to also contribute to the variation in the response variable. Farms where milk yields of zero were recorded both in 2012 and 2014 were excluded from the analysis. The model was as follows:

$$y_{ijklmn} = \mu + d_i + \tau_j + \lambda_k + (d\tau)_{ij} + (d\lambda)_{ik} + (\tau\lambda)_{jk} + (d\tau\lambda)_{ijk} + f_{i(k)l} + g_{i(k)lm} + e_{i(j)(k)lmn}, \tag{1}$$

where y_{ijklmn} is the milk yield of the *n*-th farm in the *m*-th settlement in the *l*-th village cluster, in the *i*-th district, at the *k*-th time point with the *j*-th intervention (IP vs non-IP), μ is the overall intercept, d_i is the effect of the *i*-th district, τ_j is the effect of the *j*-th intervention, λ_k is the effect of the *k*-th time point, $(d\tau)_{ij}$ is the interaction of district and intervention, $(d\lambda)_{ik}$ is the interaction of district and time, $(\tau\lambda)_{jk}$ is the interaction of intervention and time, $(d\tau\lambda)_{ijk}$ is the interaction of district, intervention and time, $f_{i(k)l}$ is the effect of the *l*-th village cluster within the *i*-th district at time *k*, $g_{i(k)lm}$ is the effect of the *m*-th settlement within the *l*-th village cluster and *i*-th district at time *k*, $e_{i(j)(k)lmn}$ are the residual error terms associated with y_{ijklmn}.

$f_{i(k)l}$, $g_{i(k)lm}$, and $e_{i(j)(k)lmn}$ were considered as random effects. Heterogeneous time-specific variances and correlations were allowed for the two subsequent measurements in time on an individual village cluster, settlement and farm by using the unstructured variance–covariance structure. In addition, error covariance parameters were estimated separately for IP and non-IP villages to adjust for heterogeneity of variance detected in residual plots. Hence, the following covariance-parameters were estimated: variances $\sigma^2_{f(k=1)}$, $\sigma^2_{f(k=2)}$, $\sigma^2_{g(k=1)}$, $\sigma^2_{g(k=2)}$, $\sigma^2_{e(k=1)(j=1)}$, $\sigma^2_{e(k=1)(j=2)}$, $\sigma^2_{e(k=2)(j=1)}$, $\sigma^2_{e(k=2)(j=2)}$ and correlations ρ_f, ρ_g, $\rho_{e(j=1)}$ and $\rho_{e(j=2)}$. Model assumptions, homogeneity of variance and normal distribution of residuals were assessed by the inspection of plots of 'studentized residuals'. Scatterplots of residuals versus predicted values and quantile–quantile-plots were used to assess homoscedasticity and normal distribution, respectively. The response variable was transformed by taking the fourth root as residual plots showed heterogeneity of variance and a right skewed distribution of residuals.

A certain spill-over effect of IP-meeting participation was observed, i.e. some households from non-IP villages also participated in IP meetings. Therefore, the approach in model (1), in which intervention (IP vs non-IP) was defined by village, was unsuitable to detect an association between involvement in IP meetings and milk yield. Thus, the categorical intervention variable (IP vs. non-IP) based on village classification was replaced by the frequency of actual IP meeting participation, which had been recorded for each household. The differences in milk yield between the two time-points (Δy_{ilm}) were regressed on IP meeting participation frequency. However, acknowledging that absolute values of milk yield differences are also determined by initial milk yields, the milk yield at the first time-point was also included in the model as a covariate. Thus, a model of the following form was employed:

$$\Delta y_{ilmn} = \mu + d_i + \beta_1 y_{1ilmn} + \beta_2 x_{ilmn} + \beta_{3i} y_{1ilmn} + \beta_{4i} x_{ilmn} + \beta_5 y_{1ilmn} x_{ilmn} + \beta_{6i} y_{1ilmn} x_{ilmn} + f_{il} + \beta_{7il} y_{1ilmn} + \beta_{8il} x_{ilmn} + \beta_{9il} y_{1ilmn} x_{ilmn} + g_{ilm} + \beta_{10ilm} y_{1ilmn} + \beta_{11ilm} x_{ilmn} + \beta_{12ilm} y_{1ilmn} x_{ilmn} + e_{ilmn}, \tag{2}$$

where Δy_{ilm} is the difference of milk yields at the end of the experiment in 2014 (y_{2ilm}) and milk yield at the beginning of the experiment in 2012 (y_{1ilm}) of the *n*-th farm, in the *m*-th settlement, in the *l*-th village cluster and the *i*-th district, μ is the common intercept, d_i is the deviation from a common intercept of the *i*-th district, β_1 and β_2 are the common slopes of a regression on the initial milk yield y_{1ilm} and IP-meeting participation frequency x_{ilm}, β_{3i} and β_{4i} are the deviations from the common slopes of the regressions on y_{1ilm} and x_{ilm} for the *i*-th district, β_5 is the common slope for a regression on the cross product of y_{1ilm} and x_{ilm}, β_{6i} are the deviations from the common slope of the regression on the cross product for the *i*-th district, f_{il}, and g_{ilm} are the random intercept for the village clusters and settlements, β_{7il}, β_{8il}, β_{9il} are the village cluster-specific random slopes for y_{1ilmn} and x_{ilmn} and their cross-product, β_{10ilm}, β_{11ilm}, β_{12ilm} are the village cluster-specific

[4] Households from non-IP households participating in IP-meetings

Table 2
Summary of type of Innovation Platform meeting in Sult and Bageshwar blocks.
Source: Ravichandran et al. (2016).

Type of IP-meeting	Sult block (No. of meetings)	Bageshwar block (No. of meetings)
Market (IP core)	4	3
Feed (IP core)	2	2
Follow-up (market & feed)	53	149
Training/exposure	1	3
Institutional meeting	2	5
Total	62	162

random slopes for y_{1ilmn} and x_{ilmn} and their cross-product, e_{ilmn} are the residual error terms associated with Δy_{ilmn}.

f_{il}, g_{ilm}, β_{7il}, β_{8il}, β_{9il}, β_{10ilm}, β_{11ilm}, $\beta_{12ilm}$and e_{ilmn} were considered as random effects with mean zero and variances σ_f^2, σ_g^2, $\sigma_{\beta7}^2$, $\sigma_{\beta8}^2$, $\sigma_{\beta9}^2$, $\sigma_{\beta10}^2$, $\sigma_{\beta11}^2$, $\sigma_{\beta12}^2$ and σ_e^2. Correlations between random intercepts and slopes on the level of village clusters and settlements were allowed to make sure that parameter estimates were invariant to rescaling of the regressors (Piepho and Ogutu, 2002). Residual analysis was carried out as explained in model (1).

Models (1) and (2) were fitted using the MIXED procedure of SAS software version 9.4. Model parameters were estimated by restricted maximum likelihood method (REML) (Littell et al., 2006). Random effects were tested for significance by likelihood ratio tests before the inspection of fixed effects. Non-significant random effects were removed from the model. Fixed effects were tested using sequential Wald-type F-tests. Denominator degrees of freedom in F-tests and standard errors for parameter estimates were adjusted using the method of Kenward and Roger (Kenward and Roger, 1997). Non-significant terms were removed from the model. The factor levels of significant qualitative factors in model (1) were compared by using pairwise t-tests. Throughout the entire statistical analysis, a significance level of 5% was used.

Simple descriptive analysis was performed for adoption of technological innovations such as feeding troughs, fodder choppers and breeding improvements before and after interventions. Post-intervention data were compared between IP and non-IP households and then compared with baseline data which were derived from the focus group discussions conducted using the FEAST approach.

3. Results

This section presents an overview of innovation platform (IP) functioning and efficiency and the extent to which the IP intervention was correlated with institutional and technological innovations at value chain and household level during the study period of 24 months (Dec 2012 to November 2014) in both Sult and Bageshwar. Most of the differences were at block level rather than at village cluster level, so many of results are presented at block level while a few details are also given for village cluster level. The processes surrounding IP-meetings and interventions are presented first, followed by the apparent effects of the IP approach.

3.1. Prioritizing issues in IPs

The initial meetings were facilitated by ILRI research staff. Over time, the meetings were handed over to partner NGO staff and by the end of the project, meeting facilitation was by local government personnel. The facilitator's role was to moderate the discussions in IP meetings, to plan for the interventions without biased opinions and to facilitate individual meetings, training and exposure visits raised from IP meetings. After each IP meeting, government and non-government stakeholders gave support for the implementation of interventions agreed in the meetings.

3.1.1. Initial prioritization

The initial key issues limiting dairy development in this hilly region were the high marketing cost of dairy produce due to the scattered nature of the settlements and a shortage of feed. The Feed Assessment Tool (FEAST) which includes a participatory qualitative discussion and a quantitative household survey (Duncan et al., 2012) helped to identify the feed-related issues and to see feed constraints in a broader livelihood context.

Initial core meetings at block level helped to prioritize the issues for the IP to act upon. There were fewer core feed IP meetings than planned due to Panchayat elections which prevented gathering of farmers at block level. Follow-up meetings at village cluster and village level for feed and market related interventions were more frequent in Bageshwar than in Sult, as were trainings and meetings with development and administrative institutions (Table 2).

The issues most frequently discussed in initial meetings in both blocks by the farmers and other actors were market-related constraints including inaccessibility of villages to markets and the low milk price paid by the existing government dairy cooperatives. After the establishment of the market linkages to sell milk, other issues arose, such as low productivity due to feed and breed issues. Once IPs were established, feed-related issues were dominant topics of discussion including accessibility to improved fodder seeds, good quality concentrate feed and fodder wastage due to lack of chopping equipment and feed troughs (Fig. 2). Issues other than dairy development such as self-help group (SHG) based issues and cropping-based issues were also discussed in the IP-meetings.

3.1.2. Changes in priority issues at IP-meetings over time

Comparing the priority of issues discussed in Sult and Bageshwar across the two-year period, the Sult IPs covered many issues in the first year, but feed and market related priorities were dominant (Fig. 3). Health and breeding issues were also prominent. Farmers raised many issues with government schemes ("convergence schemes") especially the subsidies they were giving for the purchase of crossbred cows. After the first year of IP establishment, IP members in Sult reduced their engagement in IP meetings. This was due to an issue with Aanchal, the state dairy co-operative, which delayed milk payments. This demotivated many farmers and affected their willingness to participate in IP meetings due to lack of confidence in the implementation of actions in the IP.

On the other hand, in Bageshwar, where various milk marketing channels had been explored from the outset, the IP covered issues evenly throughout the two years and feed and market related issues remained the main priority (Fig. 3). Market issues were taken up continuously for 15 months which led to the formation of a SHG-based

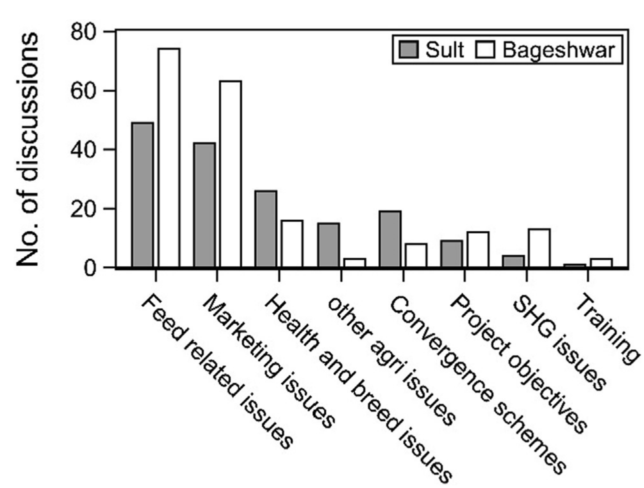

Fig. 2. Details of issues discussed in IP-meetings in Sult and Bageshwar.

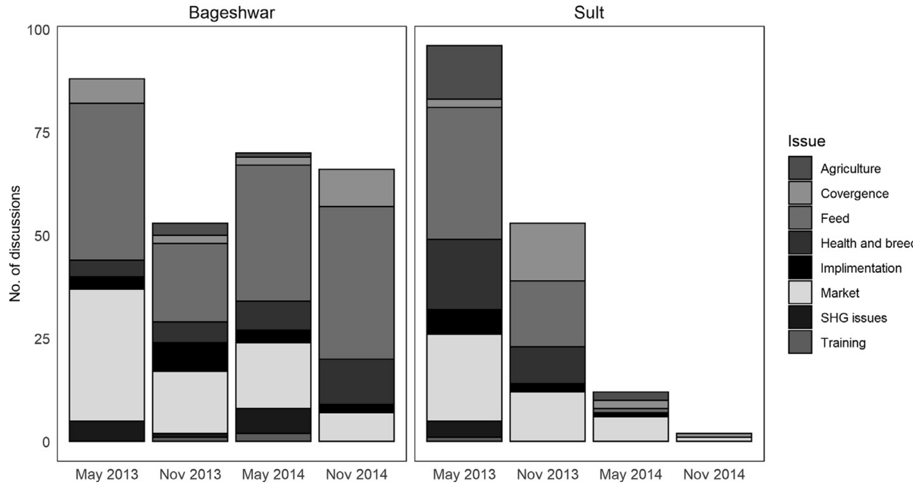

Fig. 3. Temporal distribution of issues discussed in IP-meetings in (a) Sult and (b) Bageshwar.

dairy cooperative, the establishment of rules of engaging with this dairy cooperative and the promotion of support services. Health and breeding issues were also prioritized for intervention, for example by initiating the training of Artificial Insemination (AI) workers and through veterinary health camps.

3.1.3. Follow-up of IP action plans

At the start of each IP meeting, the follow-up actions formulated at previous meetings were evaluated. Follow-up of issues were analysed at village cluster level in Sult and Bageshwar (Fig. 4). Issues were followed up more systematically in Bageshwar than in Sult. Within Sult, some village cluster level differences were observed: in Barkinda village cluster, follow-up was less comprehensive than in Saknara village cluster, even though there were more meetings in Barkinda. On the other hand, Sainj village cluster IP members were especially good in regularly following up issues and implementing the agreed action plans (Fig. 4). The outcomes of dedicated follow-up are reflected in the associated effects of interventions and are presented in more detail in the following results on adoption of technical innovations and productivity enhancement.

3.2. Participation in the IPs

3.2.1. Gender analysis of dairy producers participating

The IP meeting records were analysed in both Sult and Bageshwar to determine who attended the IP meetings. Women dominated attendance at the IP meetings: in Sult, 72% of all participants were women, while in Bageshwar the corresponding figure was 81% (Fig. 5), including some women attending more than once. More men participated in Sult (410) than in Bageshwar (244).

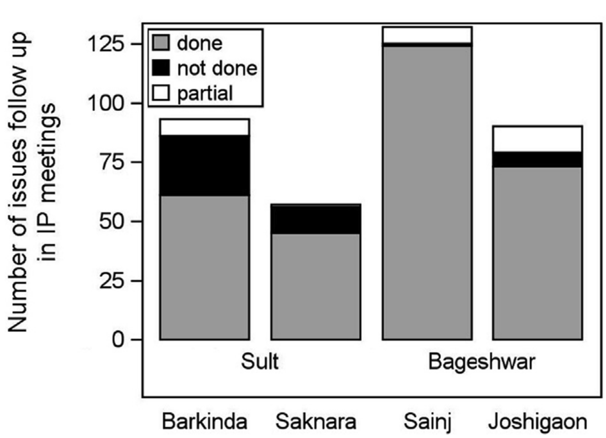

Fig. 4. Follow-up of issues in IP village clusters of Sult and Bageshwar.

Fig. 5. Gender analysis of participating farmers in IP meetings in Sult and Bageshwar.

3.2.2. Diversity of non-producers in IP meetings

At the beginning of the project, a stakeholder mapping exercise was carried out to identify the key stakeholders associated with dairy development in the study districts and at state level. Before the IP meeting phase, the stakeholders were invited through formal invitation letters and direct communication by the local project partners. The diversity of non-producer actors participating in IP meetings was higher in Bageshwar than in Sult (Fig. 6). Government officials were dominant in both blocks and these included Aanchal,[5] banks, the Integrated Livelihood Support Programme (ILSP) by IFAD, the Agricultural Department, the Animal Husbandry Department, Krishi Vigyan Kendra (KVK)[6] and the National Bank for Rural Development (NABARD). Initially, no private sector actors attended in either district although one private trader participated after 18 months of the IP meeting intervention to discuss procurement of milk with farmers. Aanchal (the government-based dairy cooperative) actively participated in Sult over many meetings,

[5] Aanchal is the government-operated dairy cooperative society in Uttarakhand.

[6] Krishi Vigyan Kendra are agricultural extension centres created by ICAR (Indian Council for Agricultural Research) and its affiliated institutions at district level to provide extension support to the agricultural sector.

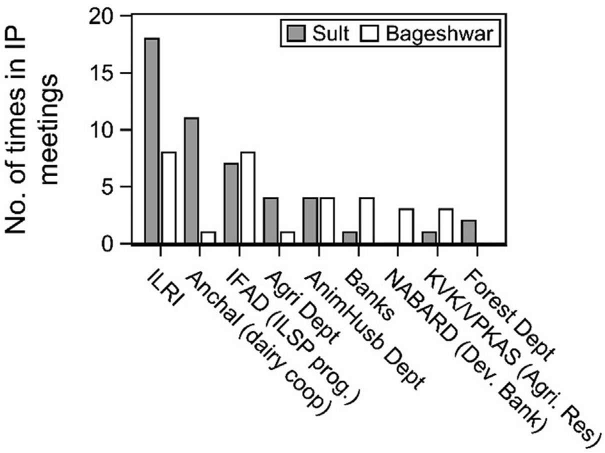

Fig. 6. Number of times individuals from different organisations participated in IP meetings in Sult and Bageshwar (Dec 2012–Nov 2014).

whereas Aanchal did not participate in Bageshwar after the first two meetings once producers started their own SHG-based dairy marketing unit at district level to sell their milk, as the issues they experienced with Aanchal were never addressed. There was evidence of banking actors in Bageshwar but not in Sult due to the distance of villages from the head offices. Representatives of an agricultural research and extension centre (KVK) located in Bageshwar participated in IP meetings. NABARD, a national development bank, took the initiative to fund dairy farmers in Bageshwar after the first IP meeting and also participated regularly in village meetings to identify beneficiaries. The effects of this participation are reflected in the Bageshwar interventions such as increased purchases of crossbred cows with high milk yield as explained below in the outcomes section.

3.2.3. Participation of dairy producers from IP and non-IP village clusters

IP meeting participant records indicate that several producers from non-IP village clusters participated in the IP meetings (Table 3). This was also reflected in the post-intervention household survey which traced participation in IP meetings. The participants from the non-IP village clusters were not invited to attend IP meetings and associated activities. There was, however, farmer-to-farmer interaction which prompted some farmers from these villages to attend IP meetings. IP meetings were open to all participants especially farmers and no restrictions were placed on who could attend. However, there was no participation from one non-IP cluster, Chouganchina. It is possible that this was due to its location, comparatively far from the main activity sites of the local implementing NGO.

Table 3
Participation of producers from IP and non-IP village clusters in IP meeting in Sult and Bageshwar.

Village cluster	Block	Type of village cluster	Producer participation in IP meetings [#]	
			Total	% Women
Barkinda	Sult	IP	651	72
Saknara	Sult	IP	747	69
Gehnaheet	Sult	non-IP	47	62
Nailwalpali	Sult	non-IP	99	57
Sainj	Bageshwar	IP	507	84
Joshigaon	Bageshwar	IP	583	76
Chouganchina	Bageshwar	non-IP	0	–
Khabra	Bageshwar	non-IP	28	89

3.3. Chronology of innovations and capacity building associated with innovation platforms in Sult and Bageshwar

A timeline of when the various innovations emerged in Sult and Bageshwar is shown in Fig. 7. These innovations fall into two categories, namely institutional/organisational and technical innovations. In addition, capacity building exercises such as training and exposure visits which arose from the IP discussions are presented.

During the first 6-month period, institutional innovations in the broad area of establishing improved access to milk markets quickly emerged. These included linking farmers to dairy cooperatives in Sult and the formation of the Jeganath Dairy cooperative by a Self-Help Group (SHG) in Bageshwar for sale of excess milk. During this period, capacity building activities included the exposure of farmers to the cooperative approach and the training of project staff on the IP approach, on dairy management, and on technical issues around feed, breed and veterinary management.

Other organisational innovations followed. For example, the national agricultural development bank, NABARD, developed a group-based credit scheme to promote improved dairy cattle breeds. Banks had generally required land as collateral for agricultural loans. Thus, women and marginal farmers were not able to borrow money because they lacked land titles. This issue was discussed at a platform meeting. To minimize the risk of payment failure and to strengthen farmer confidence, the banks and NABARD set up a new loan arrangement, following a model used by self-help or producer groups, in which a collective guarantee to repay the loan was accepted as collateral. Thus, any member of the SHG could take a loan of up to INR 100,000 (USD 1600) to buy two cross-bred dairy cattle as long as the group assumed the responsibility of ensuring that the loan would be appropriately serviced. The availability of this credit arrangement for purchasing crossbred dairy animals was not limited to participating dairy producers but also to producers who did not participate in IP meetings because the non-participating members also received the information through SHG meetings and fellow producers.

Technical innovations such as new feed options were seasonal to the rabi and kharif seasons[7]. For example, dual-purpose wheat and barley varieties were introduced by project partners with support of research institutions in the rabi season, during which period the IPs also evaluated temperate grasses, while fodder crops such as Napier grass, Sita grass and millets were tested in the kharif season (Fig. 7). After market linkages were established through cooperatives and SHGs, investments in key technical innovations were the main focus during the period June to December 2013 (Fig. 7). For example, it was during this period that farmers began purchasing cross-bred cows. Two issues raised by women in the IP meetings were the difficulties in collecting fodder from the forests and the considerable wastage of fodder due to feeding on the ground. Although the government had provided heavy-duty chaff cutters which would have reduced feed waste, these were lying idle since women were physically unable to operate them. Simple, light-weight fodder choppers were sourced by project partners during an exposure visit to the large Gujarat dairy cooperative (AMUL) which were easy for women to operate. Combined with the introduction of feeding troughs, fodder choppers reduced fodder wastage by 11% (Ravichandran et al., 2016), reducing the labour requirements for collecting feed. When the dairy producers started to maintain cross bred cows, they also began feeding high quality concentrate feeds.

After only a year, considerable amounts of excess milk were being produced in Bageshwar, mainly due to the introduction of high-yielding cross-bred cows and improved feeding. Private milk traders showed their interest in buying the milk, which was procured from the farmers

[7] The Indian cropping calendar is classified into two main growing seasons: kharif (monsoon) and rabi. The kharif season lasts from July to October and the rabi season from October to March.

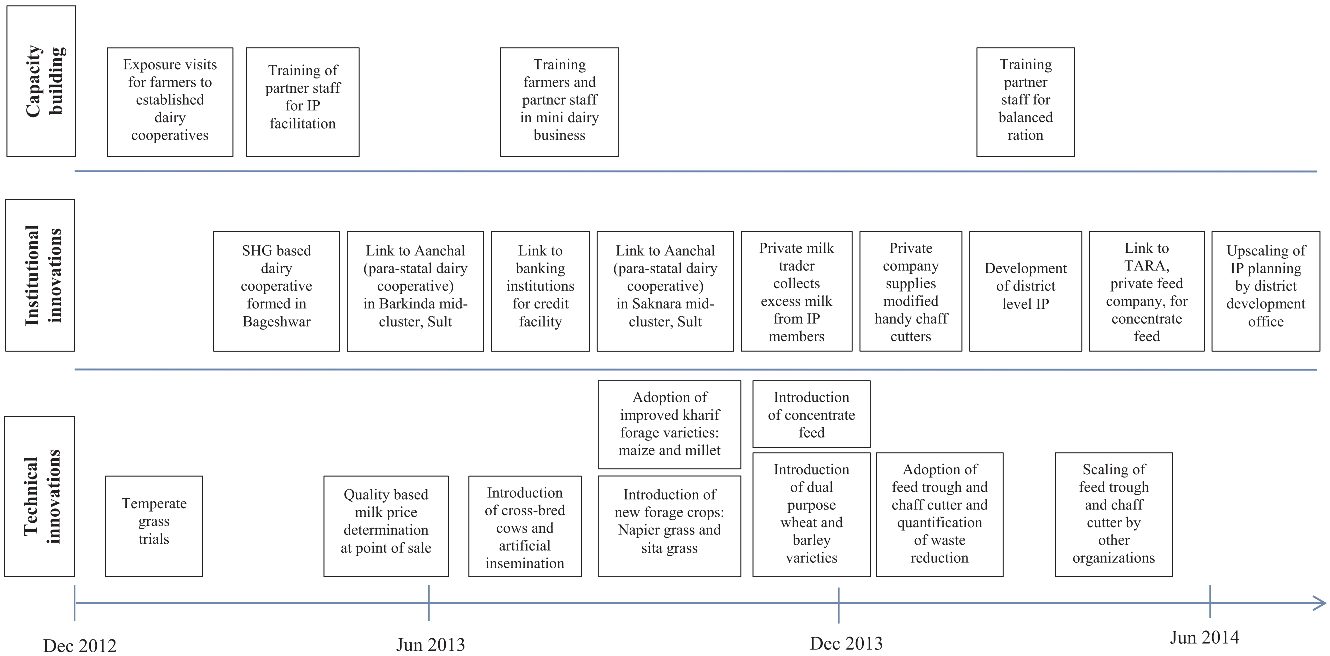

Fig. 7. Timeline of the innovations and capacity building activities established during the period of the innovation platform intervention (Jan 2013–July 2014) in Sult and Bageshwar blocks of Uttarakhand, India (Source: IP meeting documentation).

through the Jeganath Dairy cooperative. The cooperative also established a link with a private feed company to source concentrate feed in bulk at a reduced rate, allowing farmers to adequately feed their animals without threatening their returns. Towards the end of the IP intervention period of 24 months, a district-level IP was formed by the Almora District Development Officer, and the scaling of those interventions which had been most successful at the block-level IPs was initiated. Capacity building activities continued for both farmers and facilitators throughout the IP intervention period and were generally linked to the technical and institutional innovations currently being introduced.

Overall, we found that the IP process generally appeared more effective in Bageshwar than in Sult. This was reflected in a range of metrics, including in the level of participation by women (who traditionally do not have access to other development stakeholders), diversity of non-producer actors, prioritization of issues and follow-up of actions.

3.4. Outcomes associated with IP introduction

Following the investigation of the processes which evolved during the implementation of the IPs in the study sites, we analyse changes in milk yield, the adoption of technologies, and the improvement in market linkages that occurred during the period of IP implementation.

3.4.1. Associations between IP involvement and meeting frequency and increases in milk yield

One of our main research questions was whether attendance at IP meetings would be associated with increased milk yields and improved livelihoods through uptake of the technical innovations discussed during these meetings. When model (1) was fitted to the milk yield data the interaction of time (before and after intervention) and intervention (IP or non-IP) was found to be non-significant (DF = 48.7, F = 0.13, p = 0.7165), suggesting that being located in an IP village cluster was not correlated with greater growth in milk yields in IP-households compared to non-IP households. The only significant effects were the main effect of time (DF = 45.5, F = 49.52, $p < 0.0001$) and district (DF = 53.7, F = 6.59, p = 0.0131). Average milk yields increased between survey rounds from 1.03 l/day in 2012 to 2.5 l/day in 2014 (data not shown), without this increase being attributable to the IP intervention. Milk yields in Bageshwar were higher on average (2.02 l/day) compared to Sult (1.42 l/day).

However, IP and non-IP village clusters were located close to each other (Fig. 1). Although the IP meeting documentation shows a considerably higher participation in IP meetings from the IP village clusters (Table 3), there were also considerable spill-over effects with many farmers from non-IP village clusters attending IP meetings. To overcome this, model (2) was used to study the relationship between milk yield increase and IP meeting participation frequency, independent of whether households came from IP or non-IP village clusters. The categorical variable which denotes if a household was part of the IP-intervention or non-IP village cluster was replaced by participation frequency which was used as a regressor. Additionally, the initial milk yield from 2012 was included as covariate. Random intercept and slopes were found to be non-significant in a likelihood ratio test (degrees of freedom = 11, Test statistic = 0.02, $p \approx 1$) hence, further analysis was based on a linear model without random effects. Table 4 shows the results of the F-test of model (2).

No district-specific slope was significant, nor were the district-specific intercepts or the common slope of the cross-product significant (Table 4). However, the common slope for IP-participation frequency was significant (Table 4, DF = 169, F = 0.0007). The estimate for the slope was positive (0.1447 with standard error 0.0421), indicating a significant increase of milk yields with increasing participation in IP meetings (Fig. 7a).

Furthermore, the slope of initial milk yield was significant (Table 5, DF = 169, F = 119.05, $p < 0.0001$). The estimate for the slope was negative (−1.0562 with standard error 0.09680), indicating a negative relationship between milk yield and initial milk yield (Fig. 8b). Hence, households with the lowest initial milk yields in 2012 showed the largest increases in milk yield in 2014. On the other hand, households with already high milk yield in 2012 had relatively similar yields in 2014. Moreover, 23% of farms showed a negative Δy_{ilm} indicating a reduction in milk yield from 2012 to 2014, which mostly involved farms with the

Table 4
Table of sequential Wald-type-F-tests for fixed effects of model (2) fitted to differences in milk yield from 2012 to 2014 (Δy_ilm) per farm.

Effect1	Meaning	Numerator DF	Denominator DF	F-value	p-value
d_i	District effect	1	168	2.90	0.0902
β_1	Slope for initial milk yield (imy)	1	169	119.05	< 0.0001
β_2	Slope for IP-participation frequency (IP)	1	169	11.81	0.0007
β_{3i}	District-specific slope for imy	1	165	0.146	0.7085
β_{4i}	District-specific slope for IP	1	166	0.42	0.4211
β_5	Slope for cross-product (IP × imy)	1	167	1.66	0.2001
β_{6i}	District-specific slope for IP × imy	1	164	0.34	0.5595

1Random effects f_{il}, g_{ilm}, β_{7il}, β_{8il}, β_{9il}, β_{10ilm}, β_{11ilm}, β_{12ilm} were found not significant in a likelihood ratio test and were therefore removed from the model before testing fixed effects.

Table 5
Adoption of technologies, institutional innovations and the extent of market linkages in non-IP and IP village clusters before and after interventions.

Variable	Data source Baseline(Focus group discussion)		Post-intervention household survey	
	non-IP	IP	non-IP	IP
n (size of sample group/hh)	12 (142)	12 (167) [a]	24 (96)	24 (96)
Adoption of technologies				
Feed trough use (%)	3	12	5	55
Chopping fodder (%)	0	1	12	20
Concentrate feeding (%)	60	70	75	95
Artificial insemination (%)	10	15	19	38
Owning Crossbred cow (%)	1	5	5	21
Days fed improved fodder	5	10	6	52
Institutional innovations				
Cooperative membership (%)	2	10	8	51
Change dairy market channel (%)	0	2	1	14
Access to public dairy schemes (%)	1	5	1	40
Milk transactions				
Total milk sold/day mean (L/hh)	0.1	0.2	0.5	1.0
Share of milk sale (%)	5	10	13	19
Income from milk sales, mean (INR/year)	800	1200	2466	4311

[a] There were 12 FGD in each non-IP and IP area, values in parenthesis are total number of farmers participating in FGD

highest milk yields in 2012.

A final remark on the regression in model (2): a regression with two regressors results is a three dimensional 'response surface'. In this case it has the shape of a flat plane, as no cross-product terms were significant. Fig. 8 presents two transects through the response surface. Fig. 8(a) is a transect parallel to the axis of IP-participation and Fig. 8(b) is a transect parallel to the axis of initial milk yield. Participation frequencies in Fig. 8(a) show a strong left skewed distribution with few very high participation frequencies and many low frequencies. Extreme values in a regressor can have a strong influence on the estimation of the slope. The so called 'leverage' is a measure of the influence each single observation has on the estimation of the slope. In model (2) a strong positive relationship of IP-participation and leverage was found, raising the suspicion that the positive relationship of increase in milk yield and IP-participation is caused by few very influential observations. For verification, parameters of model (2) were re-estimated from a dataset where all observations with a leverage larger than twice the average leverage were excluded (Richter and Piepho, 2017). The common slopes for IP-participation and initial milk yield remained significant, but in addition also the slope on the cross-product turned significant (data not shown). Hence, results appear to be relatively robust, despite the skewness of IP participation.

3.4.2. Associations between the implementation of IPs and the adoption of technologies

The adoption rates of relevant technologies before IP establishment were determined during the focus group discussions. Except for concentrate feeding, adoption rates were low for all technologies. Nevertheless, the rates were consistently higher in households located in IP village clusters compared to those in non-IP village clusters (Table 5).

Data from the post-intervention assessment survey allowed the correlation between IP intervention and adoption of feed and breed technologies to be explored. Households from IP village clusters showed

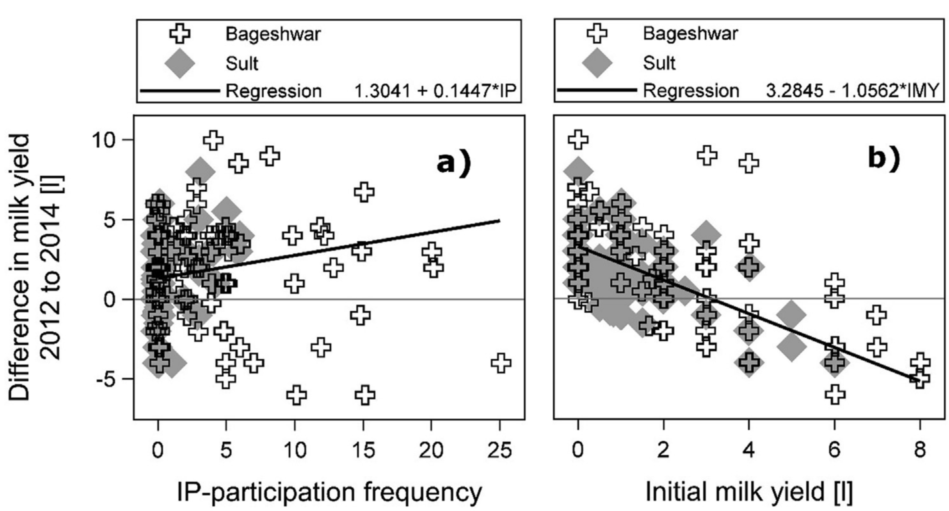

Fig. 8. Regression analysis for association of differences in milk yield between 2012 and 2014 and (a) IP meeting participation and (b) initial milk yield in 2012.

greater increases in the use of improved practices than non-IP village clusters post intervention. These practices include the use of feed troughs to reduce feed wastage, the use of artificial insemination and the use of cross-bred animals to increase genetic potential, the feeding of concentrates and use of improved fodder to increase the nutrient intake of dairy animals (Table 5). Nevertheless, considerable improvement in technology adoption within non-IP households was also recorded, especially in artificial insemination, concentrate feeding and the use of crossbred cows.

3.4.3. Changes in institutional linkages and milk marketing

Although households in IP village clusters showed stronger institutional linkages and greater milk market integration than households in non-IP village clusters, we nevertheless found considerable differences in the changes to institutional linkages and milk marketing behaviour. Households from IP village clusters changed their marketing arrangements and took up membership of either government-based co-operatives or SHG-based dairy cooperative groups far more than non-IP households did, although these households also improved their co-operative membership (Table 5).

The volume of milk sold, the share of milk sold and the income from selling milk all improved considerably between the two observation points for both IP and non-IP households. While the absolute increases were much greater for the IP households, the relative increases were similar (Table 5).

4. Discussion

The objective of the study was two-fold: Firstly, to identify the processes that evolved within a set of local innovation platforms over the study implementation period and secondly, to investigate any associations between the IP intervention and livestock productivity, technology adoption, institutional linkages, milk sales and dairy income. For this assessment, intervention sites and comparison sites had been identified before the establishment of the IPs. However, it became clear that the intervention sites showed consistently higher levels of dairy productivity, technology adoption and institutional linkages before the intervention commenced. This may have been due to the contribution of development partners in selecting the intervention sites, a common phenomenon in research for development projects. In order to explore possible links between the IP intervention and selected outcomes despite these pre-intervention differences, we looked at changes in the relevant characteristics over the study period rather than only the absolute values after the intervention. Ours was not an experimental study in that there was obvious selection bias borne of embedding the investigation within a development context. Thus, despite the various statistical approaches we employed to account for pre-existing differences and spill-over effects we cannot claim direct causality between our intervention (implementation of local IPs) and the various organisational and technical innovations that we observed. Nonetheless, our study uncovered a series of noteworthy associations between the use of IP's and various institutional and technical innovations. Moreover, our study is unusual in following the IP process systematically with baseline and endline surveys, a mixture of quantitative and qualitative data and a detailed investigation of the processes occurring within IP's over the course of their implementation.

The IP approach allowed for collective action which was associated with the establishment of market linkages from the bottom up, a result that would have been challenging for individual producers to achieve. Rapid innovation followed across the study sites and especially in IP villages. A range of stakeholders appeared to benefit: dairy producers achieved better prices and improved access to markets to sell their milk as well as gaining access to capital to invest in feed and breed innovations; banks were able to access new customers who benefited from new credit arrangements for development activities through dairy production with group-based collateral arrangements; feed sellers became involved as there was increased demand for feed because of an increase in the number of crossbred cows; animal husbandry departments used the IPs to promote extension activities and identified issues related to dairy producers. These findings support previous arguments that IPs can broaden development activities and allow institutional innovation along with technological innovation (Schut et al., 2018). The market appeared to act as an incentive for farmers to invest in feed technologies and to purchase high-yielding dairy animals because they had the confidence that they would be able to sell their milk at attractive prices. Initial participation of farmers in IPs was probably motivated by their desire for knowledge and skills and by curiosity. Longer-term participation may require economic and material incentives (Mulema, 2012) and even in the short duration of the present study these incentives seem to have been critical to successful outcomes. This study indicates that women participated more than men in both blocks because of their greater involvement in dairy production which is linked to high outmigration of men to nearby cities due to lack of employment and income-generation activities in the study region (Mamgain and Reddy, 2016). The study suggests that the perceived benefits of participation, including income increases and livelihood enhancement, also encouraged other farmers to participate in IP dialogues.

The outcomes in the Bageshwar IP were more striking than in Sult, especially regarding the increases in milk yield, milk sales and follow-up of issues. In Bageshwar more crossbred cows were purchased and this allowed higher milk yields. An important underlying factor was participation of a wider range of stakeholders in Bageshwar compared to Sult including NABARD (the national rural development bank), a private bank and the local animal husbandry department. These actors promoted credit for the purchase of crossbred cows and training of local resource persons on artificial insemination which supported the genetic upgrading of the participants' dairy herds. It may be argued that this was supported by easier market access in Bageshwar compared to Sult, which allowed for the establishment of the SHG dairy cooperative. This then provided the dairy producers with enough confidence to invest in crossbred cows as they had access to a market to sell their milk. The cooperative also facilitated feed supply. Discussions of issues in IP meetings were very wide-ranging and continuous throughout the project due to the diversity of stakeholders. Bageshwar was nearer to Almora which is where the headquarters of all development departments are located and this made their participation easier than in Sult. Previous studies have also found that co-evolution of innovations happens more readily when platforms are highly dynamic and distributed in composition rather than being static and drawing from a narrow stakeholder base (Boogaard et al., 2013; Kilelu et al., 2013; Nederlof and Mariana, 2011). Stakeholder groups are more likely to be involved and support the solutions when they are part of the decision making process (Neef and Neubert, 2011) and this was evident in this study where financial institutions acted rapidly to adjust credit arrangements. Another reason for the more positive outcomes in Bageshwar was the presence of SHGs in Bageshwar which supported non-participating household producers through the diffusion of information and technologies. A similar finding can be seen in a previous study (Pamuk et al., 2014) where the adoption of crop management practices was different in different IPs depending on the previous social capital in that area. Social capital can help to build knowledge diffusion (Semeon et al., 2013).

The regression results indicate that initial milk yield was negatively correlated with further increases in milk yield. Those animals which had high milk yields at the beginning of IP process did not show any major change in milk yield. This was likely because those farmers, who had already adopted crossbred animals and feed technologies, already had near-maximum milk yields. The farmers who had low milk yield to start with were the ones who benefitted from interventions because of adoption of crossbred cows and improved fodder and feed technologies. Participation in IP meetings may have helped them to gain the knowledge necessary to increase the productivity of their animals and increase their production.

Our results indicate that increases in milk yield and technological and institutional change occurred not only in intervention village cluster households but also in households from non-IP village clusters. This may have been linked to their participation in IP meetings, as shown by the regression results, indicating that participation in IPs enhanced their interaction with participating stakeholders. This in turn was linked with increased adoption of crossbred cows supported by financial institutions. They also appeared to benefit from the new institutional arrangements for the sale of milk. As the non-IP village clusters were in close proximity to the IP village clusters, peer-to-peer diffusion of innovations presumably occurred and is indeed key for scaling (Hendrickx et al., 2015). It is a positive finding that innovative processes and benefits attracted producers from nearby communities, and this has important implications for using IPs to bring about change at scale. From a methodological point of view, we found that selection of communities that are close to each other weakened the relationship between the intervention and outcomes due to spill-over effects. There is evidence that innovation capacity can go beyond the members of the platform and can spread to non-participants as the participants share their new experiences and learning with others (Boogaard et al., 2013). Future studies aimed at quantifying the impact of IPs should take account of the need for geographical separation of intervention and non-intervention communities.

On the issue of scaling, our work suggests that simple technical innovations such as feed troughs, choppers, improved fodder and crossbred cows can be directly scaled up by the participating stakeholders. On the other hand, scaling the organisational innovations is more dependent on effective innovation platforms as these innovations are more complex in nature (Duncan et al., 2015; Hendrickx et al., 2015) and require consensus among many stakeholders which in turn is based on dialogue and negotiation.

Women are often excluded or poorly represented in value chain projects and women's issues regularly remain unnoticed (Kaaria et al., 2016). Because the participation of women in this project was so strong, important issues linked to gender roles, including fodder wastage and lack of access to milk markets, were specifically addressed, which would not have been possible if the IPs had been dominated by men. It is important to note that understanding the issues and roles of women and men beforehand is important so that IPs can help to support relevant solutions (Mulema et al., 2015; Ravichandran et al., 2016). It appears that because participating stakeholders from different organisations recognised issues and roles pertaining to women dairy producers, relevant constraints were addressed more effectively. Promoting these aspects in disseminating and scaling IPs requires a particular engagement with development actors, emphasising the importance of the process rather than the dissemination of technical solutions. In many cases, this is contrary to established hierarchic extension systems, which are not geared towards collaborative identification of locally adapted interventions, despite such an approach having obvious advantages in complex systems.

5. Conclusion

This study considered how IPs can contribute to changes in agricultural production and rural livelihoods at various levels. The main contribution of this paper is to provide indicative evidence that IPs not only help with technology innovation but are also associated with improved institutional arrangements to enable market innovations. Improved marketing arrangements were quickly achieved because farmers and other stakeholders had clear incentives to initiate these changes. These institutional changes apparently attracted new farmers into the IP approach even though they were not initially members of the innovation platforms. Strong participation of women in the IPs ensured that gender-related constraints were identified and that development actors initiated actions to address these issues which would not have been possible otherwise. This study concludes that the specific innovations or interventions that we observed during the IP implementation phase were often determined by factors specific to the IPs' context. Dairy milk market establishment was very rapid in Bageshwar where the strong local institutional base in the form of SHGs facilitated the scaling of the interventions. Adoption of technologies and organisational innovations was also fast in Bageshwar which appeared to be linked to the involvement of diverse stakeholders including banks, NGOs and government organisations. Different stakeholders facilitated the follow-up of agreed action plans in Bageshwar. Although the study had limitations including the short time-scale of investigation, the limited number of study sites, the non-random establishment of the IPs and the effects of spill-overs caused by the proximity of target communities, the data provide rare albeit indicative evidence at household and community level that the implementation of IPs is associated with both productivity and market improvements. The observations provide a base upon which to build future work on IP effectiveness.

The study gives some insights on the importance of the IP approach for enhancing a smallholder agriculture production system. Current food security challenges are characterized by complex issues involving diverse stakeholders which need ways of working together to achieve their goals. Based on the positive outcomes reported here and in similar studies we recommend that agricultural development decision makers consider more widespread use of the IP approach to move us on from the conventional pattern of mandating technologies which generally results in low adoption. IP's appear especially useful when complex changes are required as was the case for market development and credit arrangements in our study. The different interventions identified as most appropriate in the two study sites highlight the need to advocate for a wider use of the innovation platform approach itself rather than simply scaling the innovations that emerged from the IP process in this study. Active and long-term engagement with development policy stakeholders will be essential to bring enduring and sustainable changes in approaches to agricultural and rural development.

CRediT authorship contribution statement

Thanammal Ravichandran: Writing - original draft, Conceptualization, Investigation. **Nils Teufel:** Writing - review & editing, Methodology, Data curation, Supervision. **Filippo Capezzone:** Formal analysis. **Regina Birner:** Supervision, Funding acquisition. **Alan Duncan:** Conceptualization, Writing - review & editing, Supervision, Project administration, Funding acquisition.

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