Perceptions of climate change and community response adaptation: Survey in Uttarakhand, Gene Campaign

Introduction

As climate change manifests in changing weather patterns, farmers respond by altering their cropping patterns (Kristjanson et al. 2012), which could limit their access to nutritious foods (Ericksen 2008, Sen 1983). In India, more than two-thirds of the population is involved in agriculture (Ministry of Agriculture 2004), which is in turn dependent upon the timely arrival of the annual summer monsoon (Bajaj 2012). Climate change is translating to rising mean temperatures and increasingly unpredictable weather patterns (IPCC 2007, Mitra et al. 2002), putting the livelihoods of Indian farmers at risk. Eighty-three percent of these farmers are smallholder farmers (Chand et al. 2011), who cultivate less than two hectares of land. These farmers are also often below the poverty line because much of their harvest is intended for household consumption (FAO 2002).

Given that these farmers operate on the border of subsistence, the increasingly volatile weather patterns have an adverse effect on food security, which the United Nations Food and Agricultural Organization defines as existing "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle" (FAO 2002). This definition broadens the nature of food security to encompass the preferences and nutritional needs of a population, as well as the long term sustainability and accessibility of the food source.

In recent years, late monsoons (IMD 2012) have reduced yields by forcing smallholder farmers to sow late or abandon certain crops, exacerbating food insecurity. By September of 2012, the annual monsoon rainfall was as much as 72% below average in some regions, and rainfall is expected to become less frequent but more intense, inhibiting groundwater recharge and adversely affecting irrigation prospects for the dry rabi season, which begins in mid-October and ends in mid-April (Bajaj 2012). The fragile Himalayan mountain ecosystems are particularly vulnerable, with mean temperature projected to rise 3o C over the next century (IPCC 2007). Understanding the role that perception of climate change plays in rural Himalayan food security is invaluable to informing agricultural and climate change adaptation policy.

In certain regions of the Central Himalayas, fruit cultivation has become a major income-generating activity for smallholder farmers. Historically, these areas have grown grains and vegetables for household consumption, but the need for grain cultivation has been partially offset by the increasing prominence of the Targeted Public Distribution System (TPDS), a government food security program which provides heavily subsidized wheat flour, rice, sugar, and kerosene at a small fraction of the market price (Nakkiran 2004). Khera (2011a) classifies Uttarakhand as a ‘reviving state,’ or one in which an increasing proportion of TPDS grain is reaching intended beneficiaries. While the combination of inexpensive government grain and increased income from fruit cultivation has eliminated hunger in the Nainital district, these factors have interacted with climate change to affect planting choices and alter the nutritional profile of local diets.

The confluence of these factors have affected food security in an unintended way—bringing about higher incomes and dependent food sufficiency at the expense of nutritional balance and agricultural viability in the face of climate change. During the summer of 2012, the Gene Campaign undertook a survey of perceptions of the effects of climate change and subsequent changes in agricultural decisions of households in the Ramgadh and Dhari Blocks of the Nainital District of the Himalayan Kumaon region of Uttarakhand. Farmers throughout the Central Himalayas practice highly diversified subsistence farming, with much of the vegetable and grain production intended for household consumption (Nautiyal et al. 2007). However, agricultural activities are closely tied to the natural ecosystem: fodder, in the form of grass and tree leaves, is collected from the forest for cattle, spring and river water is used for limited irrigation and household use, and wood is chopped from the forest for cooking fuel. Agricultural activities of the Central Himalayas are therefore closely tied to the surrounding forest ecosystem. This region was chosen because it presents a valuable case-study for the interaction between perceptions of climate change, government policies, such as the TPDS, and economic factors, such as the introduction of income-generating fruit production, on local food security, a scenario which is found throughout the developing world. This detailed study of perceptions of weather patterns and their relation to cropping decisions can yield a set of policy objectives for improving rural economic livelihoods and strengthening food security by increasing the sustainability of agricultural practices and aiding farmers in adapting to the effects of climate change.

Methods

From May through August of 2012, employees of the Gene Campaign surveyed 307 agricultural households in order to investigate the connection between changes in weather patterns and cropping decisions. Each year, Indian farmers rely upon the arrival and duration of the monsoon to decide which crops and when to plant. In the Garhwal region of the Uttarakhand Himalayas, the timely arrival of the monsoon in June is met with maize cultivation, but if the monsoon is late or the growth of the maize is poor, farmers then choose to plant different cultivars of millets, which are selected according to the time of the season (Singh et al. 2008). Sufficient rainfall is also necessary for groundwater recharge and for rainwater harvesting for the dry cropping season, which follows the monsoon season and relies on irrigation. In order to capture these close relationships between weather patterns, crop viability, and subsequent local food security, we surveyed perceptions of changing weather patterns, the measures that farmers have taken in response, and past, present and expected future cropping patterns.

This survey (see Annexure - Appendix A for the English translation) was initially tested in the Ramgarh Block of the Nainital District for ease of comprehension by respondents, coverage of common responses to questions, and specific relevance to the area (i.e. if cash crops comprised a substantial portion of dedicated agricultural land, then questions were revised to differentiate between cash and food crops). Free responses were solicited for open-ended questions, and the appropriate responses were marked in a comprehensive and predefined list, which was not shown to respondents, in order to avoid introducing bias.

Raw responses were then converted to percentages of all respondents and percentages of categories of respondents (by social category, age group, highest achieved education level, gender, and landholding) who gave each type of answer to each question. For example, over 99% of respondents noted higher temperatures as a recent change in weather (**Ошибка! Источник**

ссылки не найден.). All calculations are provided in the last section, Data, with the results of all questions soliciting binary responses (yes or no, noted or not noted). These results were then compared against demographic, economic, and cultural factors to examine the effects of perceptions of changing weather patterns on agriculture. We present these findings in the following section, Results. We then compare these to background factors and the larger picture of food security in the section, Discussion.

The survey (English translation shown in the Appendix) was designed and administered in Hindi and Kumaoni in an Excel sheet, processed them using the computing package, MATLAB, and undertook the analysis in this report.

Background

In this section, the background of the study population according to the conducted survey, journal articles, and other print materials are discussed.

Study Population Demographics:

The study population consisted of 307 individuals, each representing a distinct household. There were 157 men and 150 women surveyed, from 29 different villages in two blocks, Dhari and Ramgadh, in the Nainital District of Uttarakhand in Table 1 for the Dhari Block and Table 2 for the Ramgadh Block.

Table 1: Number of Respondents by Village in Dhari Block

Dhari Block Village	Households Surveyed
Aksoda	5
Bana	8
Chaukhuta	10
Gajaar	9
Kaul	10
KokilBana	10
Majheda	15
Parbada	9
Pokharad	10
Sunkiya	10
TOTAL	96

Table 2: Number of Respondents by Village in Ramgadh Block

Ramgadh Block Village	Households Surveyed
Badet	15
Bajuthiya	9
BoharaKot	11
Dadima	20
Gadgaon	6
Galla	10
Harinagar	9
Hartola	8
Jhutiya	11
Lod	10
Loshgyani	9
Mauna	16
Myauda	17
Naikana	6
Nathuwakhan	18
Orakhan	3
Simayal	11
Supi	11
Suralgaon	11
TOTAL	211

16.3% of our respondents were in the Scheduled Castes, while 83.4% were in the General Castes. These figures are similar to the Uttarakhand government statistic that 19.4% of the Nainital population is in the Scheduled Caste; our figure is likely lower because Scheduled Caste members are not evenly distributed among villages, where some village populations are more than 60% Scheduled Caste (Government of Uttarakhand 2001). There are nearly equal numbers of men (157) and women (150) in our sample.

Table 3 depicts the age and education level distributions of our sampled population. Nearly a third of respondents are under the age of forty, and half of respondents have at most a primary school education. About twelve percent of respondents have reached intermediate school or higher education.

Table 3: Percentage of All Respondents by Age Categories and Education Levels

Age Range (years)	% of Respondents	Education Level	% of Respondents
<40	30%	No formal schooling	20%
40-49	29%	Primary school	30%
50-59	22%	Secondary school	38%
60-69	8%	Intermediate school	9%
69<	11%	University degree	3%

Sorting our sample by both age and education level (Table 4) reveals that the great majority of respondents under the age of 40 have at least a secondary school education, and increasing percentages of respondents in higher age categories have received no formal schooling.

This demonstrates the trend that younger generations are increasingly likely to receive a formal education and suggests that this population sees the benefit of an education. Furthermore, six of nine university degree recipients in our sample are in the youngest age category, under the age of 40.

Table 4: Number of Respondents by Age and Education Level

	No formal schooling	Primary School	Secondary School	Intermediate School	University Degree
Age <40	4	18	54	11	6
Age 40-49	18	25	35	10	1
Age 50-59	18	28	16	4	1
Age 60-69	8	8	6	2	1
Age >69	12	14	6	1	0

Land in the settled agricultural systems of the Nainital district of Uttarakhand is arranged into small terraces carved into the mountainside. On average, 86% of a family's landholdings are rainfed, and the irrigated portion is typically reserved for vegetables, which reflects the level to which the success of smallholder agriculture depends on the predictability of monsoon rainfall. As shown in Table 11, total landholdings generally increase with age category (with the exception of the youngest two categories), which reflects the division of land among sons with each successive generation. The average household farmed 22.7 nali of rainfed land and 3.6 nali of irrigated land (20 nali is equivalent to 1 acre; Table 9). Female respondents reported average rainfed and irrigated landholding sizes that were 70% of those reported by male respondents (Table 9). Since both men and women were speaking for their households, we had expected no difference in the average landholding cited by men and women. This systematic gap in landholding size reported by men and women offers a glimpse into the differences in gender roles in land management and also suggests that knowledge of the amount of land owned is imprecise.

Although respondents in the Scheduled Castes have total landholdings that are on average 81% the size of landholdings of General Caste respondents, average Scheduled Caste irrigated landholdings are only 41% the size of those belonging to General Caste respondents. Since irrigated land requires additional water resources and labor for water transportation, this statistic highlights the persisting drastic inequalities in resource access between Scheduled and General Castes.

Livestock Holdings:

The average household in our sample keeps 2.22 cattle. Scheduled Caste members own slightly fewer cattle and buffalo than General Caste members but are much more likely to own smaller livestock, such as goats and chickens (Table 8). Cattle ownership raises household water and labor needs, with women holding the daily responsibilities of cutting and transporting grass from forests. Chickens are still very rare among households due to social stigma, and they are kept for egg production and, like goats, for meat production.

Differences in Gender Roles and Knowledge:

The roles of men and women are starkly different, with women shouldering responsibility for all housework and livestock care and men tasked with earning an income from outside jobs and field operations. The discrepancy between their workloads is considerable, with women working much longer hours at more labor-intensive tasks, as has been found in other Uttarakhand Himalayan communities (Singh et al. 2008, Nautiyal et al. 2007). Both contribute to crop cultivation, with women weeding and planting, men hoeing and digging, and both transporting harvested products.

Other gender differences are apparent when crossing gender and age as well as gender and maximum attained education level (Table 5). Table 5 shows that sampled distributions across age groups were roughly even for men and women; there were slightly more young women than young men, but more older men than there were older women surveyed. The differences in education level are very pronounced, with women at least five times as likely as men to not have received any formal schooling. Overall female literacy is low. However, we find that, among respondents under the age of 40, 30 men and 24 women have received up to a secondary school education, which indicates that younger generations of men and women are more likely have equal access to education than older generations.

Table 5: Number of Respondents (1) by Gender and Age Category and (2) by Gender and Education Level

(1)	Men	Women	(2)	Men	Women
Age<40	44	49	No formal schooling	9	51
Age 40-49	40	49	Primary school	45	48
Age 50-59	34	33	Secondary school	75	42
Age 60-69	16	9	Intermediate school	22	6
Age >69	23	10	University degree	6	3

Livestock Holdings

Average holding of each type of livestock by each specified category.

Education Level

Table 6: Livestock holdings for All Surveyed and by Education Level

Livestock Type	All Surveyed	No Formal Schooling	Primary School	Secondary School	Intermediate School	University Degree
Cattle	2.17	2.4	2.15	2.11	2	2.17
Buffalo	0.22	0.2	0.34	0.25	0.13	0.22
Goats	1.02	1.08	1.08	0.32	0.13	1.02
Horses	0.03	0.06	0.01	0	0	0.03
Chickens	0.57	0	0	0	0	0.57

Age Category

Table 7: Livestock holdings by Age Category

Livestock Type	All	Age < 40	Age 40-49	Age 50-59	Age 60-69	Age>69
Cattle	2.22	1.98	2.28	2.24	2.72	2.3
Buffalo	0.26	0.21	0.2	0.31	0.32	0.42
Goats	0.97	0.65	1.04	0.96	1.6	1.21
Horses	0.03	0.01	0.07	0.03	0	0
Chickens	0.11	0	0	0.51	0	0

Social Category

Table 8: Livestock holdings by Social Category

Livestock Type	All	Scheduled Castes	General Castes
Cattle	2.22	1.84	2.3
Buffalo	0.26	0.16	0.28
Goats	0.97	1.98	0.77
Horses	0.03	0.02	0.03
Chickens	0.11	0.68	0

Average Size of Landholding (nali)

Average size of reported irrigated and rainfed landholding for each category; 20 nali are equal to 1 acre.

Table 9: Average Landholdings for All Surveyed, by Gender, and by Social Category

	All Surveyed	Men	Women	Scheduled Castes	General Castes
Rainfed Land	22.71	26.47	18.75	20.32	23.23
Irrigated Land	3.59	4.48	2.65	1.62	3.99
Total Land	26.3	30.95	21.4	21.94	27.22

Table 10: Average Landholding by Education Level

	No Formal Schooling	Primary School	Secondary School	Intermediate School	University Degree
Rainfed Land	19.53	23.22	22.31	29.25	23.75
Irrigated Land	2.1	1.78	4.27	8.96	6.88
Total Land	21.63	25	26.58	38.21	30.63

Table 11: Average Landholding by Age Category

	Age < 40	Age 40-49	Age 50-59	Age 60-69	Age>69
Rainfed Land	21.42	20.16	20.46	29	33
Irrigated Land	3.4	3.8	2.09	7.04	3.97
Total Land	24.83	23.96	22.55	36.04	36.97

Results

In this section, major findings regarding respondents' perceptions of weather patterns, changes in cropping patterns, and relationships that emerge among these two factors and cultural and economic conditions are presented.

Observed Changes in Weather Patterns:

We find that almost every surveyed farmer has noticed that weather patterns are changing. All female farmers and 99% of male farmers said that they had noticed substantial changes in recent weather patterns compared to those of preceding years

(**Ошибка! Источник ссылки не найден.**). Respondents observed changes in weather patterns (**Ошибка! Источник ссылки не найден.**), such as higher temperatures (96% of respondents), increased unpredictability of weather (65%), a longer summer season (79%), reduced amount of rainfall (62%), and later arrival of rains (77%).

These data indicate that the global phenomenon of climate change is having pronounced effects at the local level. The great majority of farmers stated that increased unpredictability of weather is a recent phenomenon, and the fact that farmers also note the delayed arrival of rainfall and temperature differences as other manifestations of changing weather reveals that predictability of rainfall and temperature are highly relevant to their agricultural practices and livelihoods.

Effects of Perceived Changes in Weather Patterns:

In elaborating on the effects of these changes in weather patterns, respondents revealed that concerns about weather related primarily to food cultivation and food security (**Ошибка! Источник ссылки не найден.**). The most frequently noted effects of changes in weather patterns included changes to the length of the growing season (81% of all respondents), increases in pests and diseases (67%), food insecurity (86%), and decline in yield (89%). Other effects that were less commonly mentioned were the loss of plant and animal species (27%) and soil degradation (12%). These data expose the close relationship between the reliability of weather patterns and food cultivation, and more strikingly, they reveal the detriment to crop cultivation already posed by the effects of climate change.

Measures Taken in Response to Changes in Weather Patterns

Respondents, however, noted that they had taken adaptive responses to these effects of changing weather patterns (see question 4.1 of the survey). Responses varied widely (**Ошибка! Источник ссылки не найден.**), and the most common responses were that farmers had planted new crops altogether (57% of respondents), planted trees (52%),shifted planting times (41%), increased the frequency of seed exchange with other farmers (34%), changed their cropping system (33%), planted faster maturing varieties of existing crops (24%), planted different varieties of existing crops (21%), and implemented rainwater harvesting (11%). Respondents who were noted as having planted trees planted additional fruit or wild trees either on their own property, as a form of agroforestry, or within the government-owned forested areas, which farmers often access for firewood or cattle fodder. Just 5% of respondents said that they have done nothing in response, and only 2% stated that they did not know what to do in response.

While these responses highlight the adaptability of farmers to adverse and changing environmental conditions, they also expose the limited palette of resources accessible to farmers. For example, planting different crops or varieties is a prominent measure that farmers have taken in response to changing weather patterns, but the use of such knowledge is hampered by poor seed access and the lack of other agricultural infrastructure.

The Present and Projected States of Crop Cultivation:

We surveyed the food and cash crops most commonly grown by households, those that have declined in cultivation over the preceding five years and those that are projected to decline in coming years. To learn about presently cultivated food crops, we asked about wheat, finger millet, legumes, rice, and maize, and we found that more than two-thirds of all respondents grew all of these crops except rice (**Ошибка! Источник ссылки не найден.**).

More than 99% of these respondents grew these crops exclusively for household consumption. Since these grains and legumes are intended solely for household consumption, they figure prominently into household food security. Aside from grains, respondents also commonly grew cabbage (including cauliflower, as the same Hindi term is used to describe both), potatoes, and peas, with at least 80% of respondents who grew these crops stating that they were intended for both sale and household consumption. These vegetables therefore also comprise a part of household food security, but they are also grown for income-generation.

When asked which crops had declined over the past five years (**Ошибка! Источник ссылки не найден.**), respondents most often responded with wheat (73% of respondents), potato (49%), finger millet (33%), peas (25%), maize (23%), and cabbage (20%). Together, these crops comprise the most commonly grown vegetables and grains for household consumption, which suggests that household food security is growing less dependent on household food production.

Although unfavorable weather was the most commonly cited reason for the decline of all of these crops, the reasons given for the declines of grain and vegetables differed greatly. At least 21% of all reasons given for the declines of grains were that other crops were available, whereas this reason only represents less than 8% of the reasons given for the decline in cultivation of peas, potatoes, and cabbage. This demonstrates that grains, which are cultivated mainly for household consumption, are more likely to be displaced by other crops than vegetables, which can be both sold and eaten at home.

Grains are also much more likely than vegetables to be said to be declining in cultivation due to low yields and the existence of more profitable crop options (**Ошибка! Источник ссылки не найден.**). Respondents' statements that yields and returns of grains are low seem to relate more to economic profit than to resilience to difficult weather, since grains were also described as being hardy against adverse weather. Finger millet was twice as likely as other crops to be declining in cultivation due to the dearth of labor, which may relate to the difficulties in harvesting and processing because of the small size of the grain and the tough husk.

When asked which crops would be important for the future (**Ошибка! Источник ссылки не найден.**), respondents most frequently mentioned French beans, cabbage, maize, finger millet, peas, potatoes, and other legumes. When asked for reasons for their choices (**Ошибка! Источник ссылки не найден.**), the value of these crops as food was overall the most frequently mentioned. However, cabbage, French beans, peas, and potato were more likely to be named because of their value as a source of cash income than as food. Furthermore, respondents frequently noted that French beans, peas, and other legumes were important for their contribution in sustaining soil fertility; whereas contribution to soil fertility represented only 1% of responses for the other frequently mentioned crops in this category, 10%-25% of reasons given for these legumes were that they were better for soil fertility. The great majority of respondents had at most intermediate school education, which likely precluded a thorough biology education. Thus, the concurrence between their agricultural knowledge with the scientific understanding that the roots of legumes fix nitrogen and therefore enrich the fertility of soil demonstrates that traditional experiential knowledge can precede scientific findings of validity and perhaps be used to inform such studies.

In addition to these food crops, respondents cultivate peaches, pears, apples, plums, and apricots as cash crops and sell their produce to nearby cities, such as Haldwani and Delhi. Over the past few decades, fruit cultivation has brought relative economic prosperity to this region. Respondents were asked whether they cultivated fruit and whether they noticed production changes in their orchards. **Ошибка! Источник ссылки не найден.** displays these responses, showing that 80% of respondents grow apples, 90% grow plums, 88% grow pears, 90% grow peaches, and 84% grow apricots. Apples and apricots, which respondents most commonly believed to have declined in production, are also grown by the smallest percentages of respondents: the decline of these two fruits is reflected in both the proportion of people growing them and the observations of those same people. The majority of respondents believe that cultivated fruits, with the exception of peaches, have declined in production. This suggests that the reliability of the fruit economy is weakening. Nonetheless, the ubiquity of fruit production indicates that it continues to compete with household food cultivation for land. The ascent of the apple-growing regions in Himachal Pradesh to higher altitudes, as annual mean temperatures continue to rise at lower altitudes, is well-studied (Rana et al. 2009). In contrast, peaches have higher temperature tolerance than the other fruits and are therefore typically found at lower elevations, which could explain their growing prevalence in this region (Sati and Kumar 2004). Another factor is that peaches have higher market prices than all fruits, except apples, so market price does not explain the decline of apple production.

Pesticide and fertilizer use are indicative of the degree to which crops grown are suited for a given environment. We did not solicit detailed information on amounts used, but 99% of all respondents use cattle manure as fertilizer, 85% use chemical fertilizer, only 7% use bio-pesticides, and 92% use chemical pesticides. The soil fertility and quality is highly variable, making the addition of manure or chemical fertilizer necessary for many regions. Nautiyal et al. (2007) found that introduced vegetables, such as tomato and bell pepper, are more damaging to the surrounding environment, due to increased chemical fertilizer and pesticide use, and require greater energy inputs, in the forms of fertilizer and human labor, than traditional grains, such as millets, rice, and wheat. The high chemical fertilizer and pesticide use rates reflect that the current selection of crops is not well-adapted to the Nainital region.

Individual farmers pointed out that their orchards would die off completely from infestation by beetle larvae if they were not regularly sprayed with chemical pesticides. This input not only requires monetary resources but also damages “human and animal health, and beneficial plants and soil organisms;” pesticides can also contaminate water resources and aquatic ecosystems (USDA 1998). Other farmers stated that they seldom used chemical pesticides on crops intended for household consumption, which is perhaps a sign that they recognize that chemical pesticides are harmful to health, but all crops intended for sale (cabbage, potatoes, peas, fruits) were subject to use of chemical pesticides.

Rhesus monkeys were also commonly cited as major pests to all crops, and farmers observed that local rhesus monkey populations had grown considerably over the past three years, having previously been confined to lower elevations. All crop cultivation is susceptible to damage by monkeys, and farmers in the block of Dhari named monkeys as the main reason that they have stopped cultivating maize. Short of killing these monkeys, which is culturally taboo for Hindus, farmers had no viable methods of preventing monkeys from damaging crops.

Crops and Sensitivity to Changing Weather Patterns :

Respondents were asked to name food crops that they believed were susceptible to changing weather patterns, others that were resilient to changing weather patterns, and crops which were no longer grown but would also be resilient to changing weather patterns.

The crops most commonly described as poorly suited to changing weather patterns (**Ошибка! Источник ссылки не найден.**) are tomatoes (76% of all respondents), peas (67%), cabbage (59%), chilies (47%), French beans (22%), and potatoes (22%). A common theme is that these are all recently introduced vegetable crops, of which peas, cabbage, and potatoes are the most frequently grown.

The crops most commonly mentioned as resilient to changing weather patterns (**Ошибка! Источник ссылки не найден.**) are more diverse than those described as unable to cope with changing weather patterns (**Ошибка! Источник ссылки не найден.**). Starting with the most frequently mentioned, crops resilient to changing weather patterns are finger millet (75% of all respondents), maize (50%), barley (50%), wheat (19%), foxtail millet (18%), and barnyard millet (14%). A characteristic shared by these crops is that they are all grains, which respondents also believe to be the most likely to decline in the future due to the availability of other, potentially more profitable, crop options (**Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.**).

These responses indicate that farmers continue to change the crops they grow to cope with economic and environmental conditions. As a result, several types of crops are no longer cultivated in the region, and resources for reviving them continue to dwindle. We asked respondents if any of these past crops would also be resilient to changing weather patterns (**Ошибка! Источник ссылки не найден.**). Starting with crops most frequently named by respondents, useful previously grown crops were finger millet (48% of all respondents), barley (38%), maize (30%), barnyard millet (21%), and foxtail millet (20%).

These are the same crops that are described as presently grown and resilient to changing weather patterns, showing that the crops that these farmers are increasingly less likely to grow the crops that they believe to be resilient to climate change.

One crop for which these data are less clear is wheat. Wheat was the most frequently mentioned crop when respondents were asked which crops had declined in the preceding five years. Respondents most often gave unfavorable weather as the cause of declining wheat cultivation, but this was the case with all crops said to have declined in cultivation over the preceding five years. Wheat was also named by 11% of respondents when they were asked which crops suffered most from changing weather patterns (**Ошибка! Источник ссылки не найден.**). However, respondents also frequently described wheat as resilient to changing weather patterns (19% of respondents, **Ошибка! Источник ссылки не найден.**) and also categorized it as a crop that was no longer grown but believed to be resilient to challenging weather conditions (7%, **Ошибка! Источник ссылки не найден.**).

Three-quarters of our respondents grow wheat, and wheat is also provided cheaply by the government through the TPDS system. One possible explanation for these contradictory assessments of wheat is the sheer diversity of environmental and climatic conditions experienced across our sample, where wheat might prove more resilient to mid-range temperatures, but fare very poorly in a nearby village, where temperatures could be higher due to different elevations and positioning on the mountain faces. For example, at the same elevation in the Uttarakhand Himalayas, citrus and peach fare better on south-facing slopes whereas plums, some apples and pears are most suitable to the north-, east-, and west-facing slopes (Sati and Kumar 2004). Wheat has been shown to be adversely affected by higher temperatures, which have been widely noted by respondents, and the decline of wheat yields have also been demonstrated to result from higher temperatures with climate change (Lobell et al. 2012). Furthermore, it is likely that in areas where lower temperatures are favorable for wheat, grain cultivation is becoming displaced by more profitable fruit cultivation, which will also thrive in lower temperatures, and in areas where temperatures are slightly higher, wheat cultivation is more visibly suffering.

In order to measure preferences, we asked respondents which crop they believed to be the most nutritious. 73% of all respondents responded that finger millet was the most nutritious crop; 28% noted wheat; and 1% believed maize to be most nutritious. One notable trend is that younger respondents are less likely than older respondents to note finger millet as the most nutritious crop (57% of 93 respondents younger than 40 years old and 80% of 214 respondents older than 40 years old) and twice as likely to note wheat (47% of respondents younger than 40 years old and 19% of respondents older than 40). Another related trend in education level emerges—those with less formal education are more likely to describe finger millet as the most nutritious crop than those with more, with 80% of 153 with primary schooling or less and 66% of all 154 respondents with greater schooling. Complementarily, those with greater formal education were more likely to state that wheat is the most nutritious crop: 21% of those with primary schooling or less and 35% of those with greater formal education. This suggests that belief in the superior nutrition of finger millet is part of the local traditional knowledge and is fading with the older generations, who did not have as much formal schooling as the younger generations (Table 4). Younger generations are also growing accustomed to present agricultural practices and subsequent diets—seeing more wheat in their diets and less finger millet and perhaps associating wheat with greater acceptability in mainstream culture. It is worth noting that although rice is consumed in all households given the reach of the TPDS, it was not mentioned by any participants. This suggests that participants were not simply describing the most commonly encountered foods in their diet but actually judging the quality of their diets.

A clear pattern emerges from these data: farmers are increasingly making the choice to grow vegetables, which are ill-suited to changing weather patterns but economically profitable, instead of grains, which they prefer and believe to be resilient against changing weather patterns but to have little economic value.

Impacts of Changing Weather Patterns on Workloads and Natural Resources :

The adverse effects of changing weather patterns extend beyond crop cultivation and permeate the livelihoods of our surveyed population. Respondents observed dwindling natural resources, increasingly difficult workloads, and declines in agricultural productivity. Specifically, the great majority of respondents have described decreases in availability of fuel wood (83% of 305 respondents), grass for fodder (87% of 305 respondents), pasture land (89% of 297 respondents), and spring water (74% of 307 respondents, with 21% stating that spring water availability has remained the same) (**Ошибка! Источник ссылки не найден.**). The total number of respondents varies in each category since not all respondents accessed each resource.

In addition, respondents state that the roles of men and women have changed as a result of changing weather patterns (**Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.**): men are spending more time on agricultural cultivation (61% of all respondents) and taking up additional employment, in the forms of paid labor (16%) or other jobs (14%); women are also spending more time on agricultural cultivation (50%) and more time at home (31%), and they have had to travel farther for collecting natural resources. Thirty-seven percent of all respondents mentioned increased commutes for finding and fetching water; 48% ventured farther for chopping and transporting wood; and 49% traveled a greater distance to harvest grass for their cattle.

Coupled with the finding that, with the exception of peach cultivation, fruit production is believed to be declining by the great majority of respondents, these data indicate that present agricultural practices and sources of income are neither reliable nor sustainable. In the following Discussion section, we contextualize these findings in demographic and cultural factors, and we discuss the impact of economic and environmental factors and consequent cropping decisions on household food security, livelihoods, and agricultural sustainability.

Conclusions

In this section, the reasons that surveyed farmers are less likely to cultivate the very crops that they deem useful in withstanding the effects of changing weather patterns are explored. We then tie these to effects on food security and the sustainability of smallholder agriculture and rural livelihoods.

Our analyses show that Himalayan farmers in the Nainital District of Uttarakhand are noticing higher temperatures with late and reduced monsoon rainfall and that these respondents believe adverse weather to be the most pressing factor in declining crop cultivation. These farmers also grow grains primarily for household consumption, and although farmers believe local grain species, especially finger millet and barley, to be the most resilient against observed changes in weather and to be the most nutritious crops, they are also less and less likely to grow these grains. In contrast, farmers are increasingly likely to grow vegetables and fruits, which generate income but which suffer the most from observed warmer weather and reduced rainfall, both according to respondents and also suggested by past studies (Rana et al. 2009, Moretti et al. 2010).

This shift toward greater commercial fruit and vegetable cultivation has been seen across India—between 2004 and 2010, alone, the market arrivals of fruit and vegetables are estimated to have more than doubled, from 24 million MT to 57 million MT (Ministry of Agriculture 2012).Given the burgeoning economic incentive to cultivate fruit and vegetables, changing the variety of crops cultivated is not a viable strategy for adapting to weather. Rather, surveyed smallholder farmers adapt to adverse weather by adjusting their agricultural practices: harvesting rainwater, planting more trees, increasing seed exchange, and changing the timing of the planting of crops.

Although weather is the most immediate factor in deciding when and whether to plant, economic factors dominate the decision of what to plant. Our findings show that profitability of crop production takes precedence over and can stand in the way of dietary preferences and the long-term sustainability of crop cultivation. Whereas the demand for fruits and vegetables in neighboring towns incentivizes cultivation in the Nainital District, government-subsidized grain has eliminated demand for local traditionally grown grains. One surveyed farmer explained the absence of a local grain market by explaining that no one would pay 30 rupees for a kilogram of finger millet when wheat and rice are available at the local government grain distribution centers, also known as Fair Price Shops, of the Targeted Public Distribution System (TPDS) for 2 rupees per kilogram.

The TPDS system was designed to protect the poor and vulnerable from hunger and to draw down the glut of government grain stockpiles (Khera 2011). It has only succeeded in the former for the short term. Its growing prominence in the surveyed area has largely done away with immediate hunger but, by displacing local grain production, has fostered a dependence on government grain and thwarted the capacity of available food to meet preferences and nutritional needs at all times. This dependence became evident in a second set of semi-structured interviews. When asked what they would do if the government were to close the Fair Price Shops, farmers stated without hesitation that they would die of hunger.

In addition to providing grain directly, the Indian government also guides crop production through agricultural subsidies for pesticide and fertilizer use, with a recent government report, State of Indian Agriculture 2011-12, noting that the subsidies for fertilizers have "led to an imbalanced use of N, P, and K in states like Punjab and Haryana and has also contributed to deteriorating soil conditions" and "the expenditure on subsidies crowds out public investment in agriculture research, irrigation, rural roads and power" (Ministry of Agriculture 2012). The extent of state government subsidies of pesticide and chemical fertilizer use are reflected our finding that 85% of respondents report using chemical fertilizer and 92% report using pesticides (**Ошибка! Источник ссылки не найден.**). Some respondents have found that the survival of their orchards rely on these pesticides, which many admit to using only for saleable produce, rather than on produce intended for household consumption. Respondents in the second set of semi-structured interviews stated that chemical fertilizers have degraded their soil, finding that yields have fallen with each year of use. The observation that yields are falling in spite of increased resource use reveal that government policies have been insufficient in both accounting for the local environmental conditions of agriculture and in thoughtfully guiding farmers in the use of these subsidized resources. This inefficient use of government resources aimed at poverty alleviation is reflected by earlier studies. Fan et al. (2008) finds that agricultural subsidies for fertilizer and pesticides have been crucial in encouraging farmers to adopt new technologies but that poverty alleviation is better achieved through supporting transportation infrastructure, rural education, and further agricultural research.

Results show that respondents believe that their nutrition and the sustainability of their agricultural livelihoods given changing weather patterns rely on cultivating more grains, such as finger millet, barley, maize, barnyard millet, and foxtail millet, and their traditional beliefs in the nutrition and hardiness of millets are substantiated by past studies of millet nutrition content, compared against that of other cereals (Singh and Raghuvanshi 2012). Despite the expressed benefits of nutrition and sustainability in grain cultivation, surveyed farmers find that their decisions of what to grow are primarily determined by profitability.

Following the framework that food security is defined not only by the abatement of hunger but also by the sustainability of the food source and its fulfillment of nutritional requirements and lifestyle preferences (Ericksen 2008), we find that government policies have played a substantial role in jeopardizing food security in our study area although immediate hunger has been abated. Surveyed farmers are unable to meet their nutritional needs, their preferences, and the perceived challenges of changing weather patterns because government distribution and agricultural policies have obviated the market for the grain crops that farmers believe to be the most appropriate for these challenges. Given that challenges of changing climate will only continue to grow, Indian government agricultural and grain distribution policies need to be modified to more completely address food security among smallholder farmers.

Bibliography

Bajaj, V., "Crops in India Wilt in a Weak Monsoon," *The New York Times*, p. B1, 4 September 2012.

Intergovernmental Panel on Climate Change, "Climate Change 2007: Synthesis Report, Summary for Policymakers," Valencia, 2007.

Chand, R., Prasanna, P.L. and Singh, A., "Farm Size and Productivity: Understanding the Strengths of Smallholders and Improving Their Livelihoods," *Economic & Political Weekly Supplement*, pp. 5-11, 2011.

Ericksen, P.J., “Conceptualizing food systems for global environmental change research,” *Global Environmental Change*, doi:10.1016/j.gloenvcha.2007.09.002, 2007.

Food and Agriculture Organization of the United Nations, "Smallholder Farmers in India: Food Security and Agricultural Policy," FAO of the United Nations, Regional Office for Asia and the Pacific, Bangkok, 2002.

Food and Agriculture Organization of the United Nations, "Chapter 2. Food security: concepts and measurement (http://www.fao.org/docrep/005/y4671e/y4671e06.htm)," Food and Agriculture Organization of the United Nations, 2003.

Government of Uttarakhand, "Nainital - District at a Glance - (http://nainital.nic.in/pages/display/9-district-at-a-glance)," District Administration Nainital - Uttarakhand, Nainital, 2001.

Indian Meteorological Department, "Monsoon Reports (http://www.imd.gov.in/section/nhac/dynamic/Monsoon_frame.htm)," Indian Meteorological Department, Pune, 2012.

Khera, R., "Trends in Diversion of Grain from the Public Distribution System," *Economic & Political Weekly*, pp. 106-114, 2011a.

Khera, R., “Revival of the Public Distribution System: Evidence and Explanations,” *Economic & Political Weekly*, 46:44,45, 2011b.

Kristjanson et al., “Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa,” *Food Sec.* 4:381-397, 2012.

Lobell, D.B., Sibley, A., Ortiz-Monasterio, J.I., "Extreme heat effects on wheat senescence in India," *Nature Climate Change*, vol. 2, pp. 186-189, 2012.

Ministry of Agriculture, Govt. of India, "Agricultural Statistics at a Glance 2004," Indiastat.com, 2004.

Ministry of Agriculture, Govt. of India, “State of Indian Agriculture 2011-12,” agricoop.nic.in/docs/htm, 2012.

Mitra et al., “Global change and biogeochemical cycles: the South Asia region,” Tyson et al. (Eds.), *Global-Regional Linkages in the Earth System*, Berlin: Springer, 2002.

Nakkiran, S., "A Study on the Effectiveness of Public Distribution System in Rural Tamilnadu," The Planning Commission, Government of India, New Delhi, 2004.

Nautiyal, S., Kaechele, H., Rao, K.S., Miakhuri, R.K., and Saxena, K.G., "Energy and economic analysis of traditional versus introduced crops cultivation in the mountains of the Indian Himalayas: A case study," *Energy*, vol. 32, pp. 2321-2335, 2007.

Rana, R.S., et al., “Impact of Climate Change on Shift of Apple Belt in Himachal Pradesh,” *ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture*, 2009.

Sati, V.P. and Kumar, K., *Uttaranchal: Dilemma of Plenties and Scarcities*, Mittal Publications, 2004.

Sen, A.,*Poverty and Famines: An Essay on Entitlement and Deprivation*, Oxford: Oxford University

Press, 1983.

Singh, K., Miakhuri, R.K., Rao, K.S., and Saxena, K.G., "Characterizing land-use diversity in village

landscapes for sustainable mountain development: a case study from Indian Himalaya," *Environmentalist*, vol. 28, pp. 428-445, 2008.

Singh, P. and Raghuvanshi, R.S., “Finger millet for food and nutritional security,” *African Journal of Food*

Science, vol. 6:4, pp. 77-84, 2012.

USDA - Natural Resources Conservation Service, "Soil Quality Information Sheet

(http://urbanext.illinois.edu/soil/sq_info/pest.pdf)," United States Department of Agriculture, Washington, D.C., 1998.