MOUNTAIN CHRONICLES

A NOTE ON CROP DISTRIBUTION AND MICRO-ENVIRONMENTAL CONDITIONS IN HOLSHAL AND GHOSHUSHAL VILLAGES, PAKISTAN

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The purpose of this note is to describe and explain the distribution of crops within the terraced and irrigated areas of two adjoining Karakoram mountain villages, especially as that distribution relates to microenvironmental conditions. The information offered here supports no immediate conclusions, except the obvious ones that farmers consider the physical attributes of their plots when they decide where to grow what crops, and intervene where they can to increase the potential of a plot to support the crop it bears (Saunders, 1984; Whiteman 1985, 1988). Frequency of irrigation is the

main intervention discussed in this note. Agriculture in Holshal and Ghoshushal, as in other communities in the Karakoram, depends on meltwater irrigation (Whiteman, 1985, 1988; Butz, 1987, 1989; Kreutzmann, 1988, 1993; Vander Velde, 1989); in these villages potential evaporation exceeds precipitation by almost 450% during the growing season (Butz, 1987).

It is anticipated that the findings presented here will supplement the currently meager corpus of information on indigenous agriculture in the Karakoram (but see also, Saunders, 1984; Whiteman, 1985, 1988; Conway et

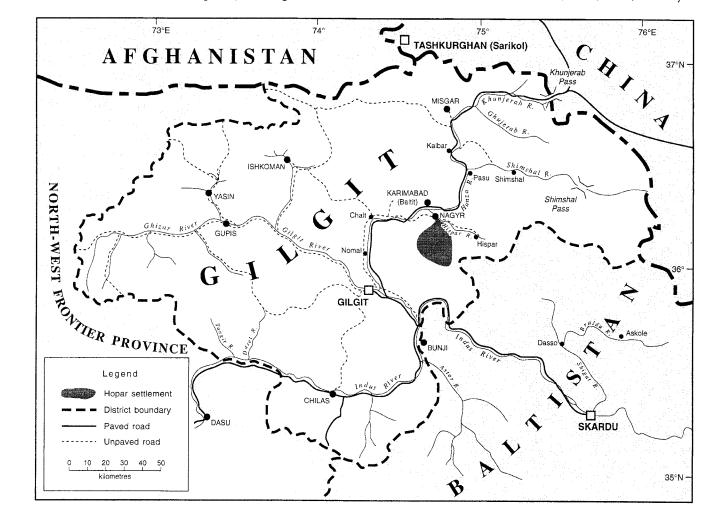


FIGURE 1. Gilgit Administrative District, Northern Areas, Pakistan (adapted from Butz, 1989:36).

FIGURE 2. The Hopar settlement (adapted from Butz, 1989:36).

al., 1985; Allan, 1986, 1989, 1990, 1991; Husain, 1986; Butz, 1987, 1989, 1993; Hewitt, 1989; Kreutzmann 1988, 1989, 1993; Vander Velde, 1989). The plane table maps—among the few detailed and precise small-scale maps of cultivated lands in the Karakoram—may be especially valuable. This research was undertaken as part of a larger investigation of meltwater-irrigated agriculture in the agro-pastoral settlement of Hopar, Northern Areas, Pakistan (of which Holshal and Ghoshushal are two of five villages), conducted during the summers of 1985 and 1986 (Butz, 1987, 1989).

Hopar is a settlement of five agro-pastoral villages in the Central Karakoram region of Pakistan's Northern Areas (Figure 1). With cultivated fields between 2,500 and 3,000 m, it is the highest permanent settlement in the former feudal kingdom of Nagyr. Today, the 73 villages of Nagyr, including Hopar, are a small and remote portion of Gilgit Administrative District. Hopar's 4,000 inhabitants occupy an extensive glacial terrace between the steep slopes of the Minapin Range and the Bualtar Glacier. They survive mainly on subsistence production from 280 ha of irrigated terraces. Agricultural subsistence is supplemented by herding in a dozen or more high pastures located on the lower Minapin slopes, or on slopes rising from adjacent glaciers. The five Hopar villages interact as a single community, and share a single meltwater source, but each is surrounded by the arable land of its residents, which is spatially distinct from the lands of other villages. The terraces of Holshal and Ghoshushal villages comprise 14 percent of Hopar's total cultivated area: 680 individual terraces on 40 ha of land (Figures 2 and 3).

The cultivated area of Holshal and Ghoshushal was mapped at 1:2,500 (Figures 4 and 5). The maps include topography, as well as irrigation channels, fields, crops, terraces, and buildings. Fifteen individual plots within the mapped area were selected for detailed study. Test plots included all field crops grown in Holshal and Ghoshushal, in roughly representative proportions: 3 fields of wheat, one barley, 3 broad bean, 3 potato, 3 alfalfa, one pasture, and one mixed pasture/orchard. The main physical inputs to crop growth, identified by Saunders (1984) and Whiteman (1985) in their reports on Karakoram agricultural systems, were measured continually for each plot from early May to mid-August (Table 1). Results were tabulated ordinally, to determine how plots (and crops, because they are not regularly rotated (Allan, 1989:138)) ranked in terms of the various inputs: an increase in the value or utility of any individual input (within thresholds) raises the agricultural potential of a plot. The comments that follow are based on the supposition that plots with the highest rankings have greatest agricultural potential. No attempt is made here to assess the complementary influence of several inputs.

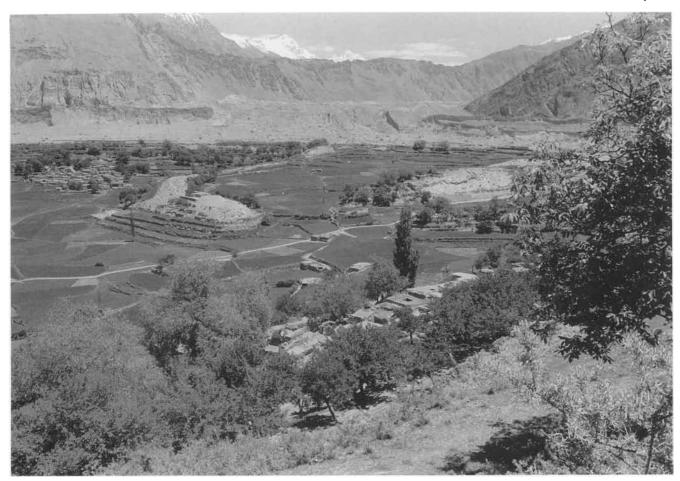


FIGURE 3. Holshal and Ghoshushal villages from the west. The two villages are separated by the jeep road which is visible middle-ground.

Ordinal data are presented in four ways. First, Table 2 ranks the 15 test plots according to each measured micro-environmental input; each row allows comparison among the plots for one micro-environmental input. Second, Table 3 provides an overview of how each plot fared in terms of seven categories of crop growth variables; each variable is represented by the single indicator (input) that was considered most representative of that variable and/or that displayed most variation among test plots (Table 1). Third, Table 4 aggregates the data for each crop category, to show which crops received the best of which inputs. Finally, Table 5 ranks crop categories according to those environmental variables that were measured for the whole cultivated area of Holshal and Ghoshushal. Comparison between Table 5 and the other tables helps assess the representativeness of the 15 test plots.

It is apparent from the tables that potato crops occupy land with the greatest agricultural potentials, at least among those plots tested. The high ranking for potato plots is due in part to manuring and fertilization; nitrate, phosphorous, and potassium levels were considerably higher for potatoes than for other plots. These three nutrients are primary fertilizer and manure components.

Organic matter is also high for potatoes. In addition, test potato plots occupy the most fertile soils in the most favorable locations in terms of radiation and water utility. This finding corresponds with results of measurements that were made for the whole Holshal/Ghoshushal cultivated area, which show that potatoes exploit high water utility and relatively great heat receipts, although bean fields tend toward greater amounts of sunshine per day, and a more southerly aspect. Beans are closer to their growing season threshold, and therefore require the advantage of a favorable exposure. Only by occupying plots with choice climatic positioning can they grow and mature, especially as their foliage inefficiently converts incoming radiation to soil and surface heat. Potato plants, on the other hand, benefit from shorter periods of sunlight diurnally and seasonally, because they require large variations in temperature for maximum carbohydrate production (Whiteman, 1988: 72).

Because they are often grown together, beans and wheat occupy plots with similar agricultural potential. In most cases beans are thinned out for fodder in late June, after releasing some leguminous nitrogen to the soil. Only a few fields of beans are required to fill the role as a wintertime dietary supplement. Occasionally, on plots

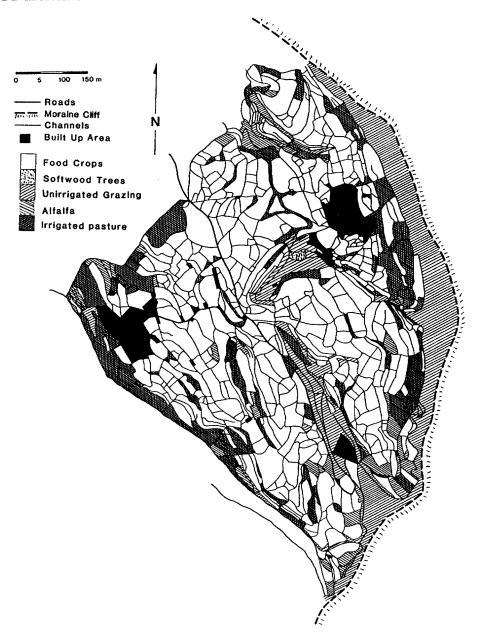


FIGURE 4. Land-use distribution in Holshal and Ghoshushal villages, Hopar settlement.

especially suited to bean requirements, wheat is thinned and beans are allowed to mature. Beans are also used as a means of periodically replenishing nitrogen deficient soil. It seems, however, that villagers exaggerate the nutrifying effects of bean crops; nitrogen levels in bean plots are high, but other soil nutrients are relatively low.

High albedo and dense soil cover inhibit the effective utilization of incoming radiation for both beans and cereal crops; albedo measurements show that wheat and especially barley reflect more short-wave radiation than other crops. In addition, humidity readings were low for cereal crops. Cereals ranked only slightly below potatoes for micronutrients (calcium through iron), and had a more favorable pH. However, their nitrate, phosphorous, and potassium levels are considerably lower, reflecting less manure and chemical fertilizer application than potato fields. Despite the availability of subsidized wheat from down country (Allan, 1990) wheat continues to occupy 70% of Hopar's terraced area. However, as potatoes become more important as a food and export crop, they are grown on the best plots, and receive the greatest inputs of fertilizer and labor, and wheat is shifted to plots with less agricultural potential. Such compromise is insightful, because potatoes respond more strongly than local wheat varieties to climatic and nutrient inputs.

Alfalfa is the main ground cover for pasture, orchard, and alfalfa plots. It is grown in fields with relatively high amounts of sunlight, but correspondingly lower water and soil inputs; it tends to occupy recently colonized terraces that are exposed to the sun, but which have poorly developed soils and are remote from warm, clean water. In addition, alfalfa and pasture receive low human and

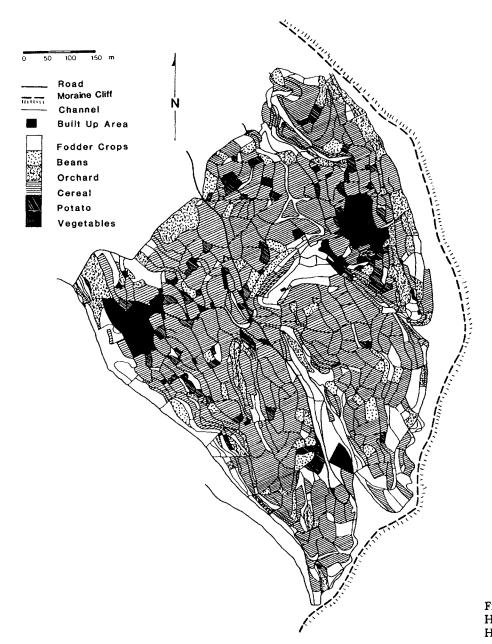


FIGURE 5. Crop distribution in Holshal and Ghoshushal villages, Hopar settlement.

fertilizer inputs; no manure is applied except by grazing stock; two crops of hay are harvested each year; plots are heavily grazed, and even natural nitrogen supplied by the plant itself has a negligible nutrifying effect. Hopar farmers apply manure and water to other crops at the expense of alfalfa, because they perceive that alfalfa is well adapted to utilize high radiation, and can overcome other deficiencies. That they are correct is demonstrated by lush alfalfa crops both in the terraced area and on non-terraced and frugally irrigated slopes above cultivation.

The preceding comments, supported by Tables 2-5, suggest that farmers in Holshal and Ghoshushal consider the potential for specific sets of micro-environmental conditions to support particular crops when they plan the distribution of their crops. In general, potatoes occupy the best plots. Cereal crops and beans are grown in

slightly less fertile locations. Fodder crops are relegated to fields with low agricultural potential. Potatoes are an introduced crop that is increasing in importance. At the same time, wheat remains the preferred and staple foodstuff. Farmers compromise by devoting better land and more fertilizer to potatoes, rather than larger areas. This is an ideal solution, because wheat thrives on relatively poorer soil if radiation is sufficiently high. Similarly, alfalfa is grown on poor plots, not because it is perceived as unimportant, but rather because it requires less moisture and soil fertility. Farmers perceive that a balanced production yields greater productivity over time than maximum production from any one crop. That the pattern identified here is not always strong is more likely due to circumstances of tenure and subsistence mode of production than to ignorance of crop requirements, especially as all households devote some

TABLE 1

Main physical inputs to crop growth potential

	Physical inputs to crop growth	reduce to	Main growth potential variables	represented by	Proxy indicators
Radiation	 sunshine hours/day aspect soil temperature surface temperature air temperature altitude 		•diurnal heat intensity •growing season duration •photosynthetic potential		•soil temperature •altitudinal variation •sunshine hours/day
Moisture	 humidity evaporation slope plot size distance from nala water holding capacity of soil irrigation frequency 		water temperaturewater utilityevaporationirrigation frequency		 distance from <i>nala</i> plot size plot evaporation irrigation frequency
Soil	•nitrate •phosphorus •potassium •calcium •magnesium •manganese •aluminum •sulfate •iron •organic matter •pH		•soil quality		•nitrate content

land to wheat, alfalfa, potatoes, orchards, and usually beans. One household's best potato land may be considered wheat land by wealthier or more fortunate householders.

Farmers attempt to overcome the contingencies of tenure and subsistence production by intervening to improve the potential of plots to support the crops they bear. Irrigation frequency is a crop growth parameter that, more than any other, can be controlled and manipulated by the Hopar farming community. Therefore, it is expected that, within the constraints of meltwater supply and community-level allocation schedules (Butz, 1987, 1989; Kreutzmann, 1988; Vander Velde, 1989), farmers choose the interval between irrigations in a way that balances inputs to various crops, and as a means of increasing overall productivity. The bottom row of each of Tables 2-5 allows comparison of frequency of water application with rankings of other variables. The three bean crops received water every 6 days on average. Cereal crops average 6.5 days between applications. As with overall agricultural potential, beans and cereal are similar in frequency of water receipt. Potatoes are irrigated much less frequently—every 10 or 11 days. Alfalfa plots averaged over 13 days between irrigations. Both orchard and pasture plots were watered more often. In all but two cases the orchard was irrigated by a trickle method, which

watered apricot trees, but not the surrounding alfalfa ground cover. It was discovered part way into the season that the tested pasture was an anomaly in terms of irrigation; it is located adjacent to an aqueduct which often overflows, so most irrigation of the plot was probably accidental.

These results suggest that the relationship between crop type and frequency of water application is stronger than crop type and any other measure of agricultural potential. Farmers clearly recognize that altering the interval between water application is a way to enhance productivity of specific crops, and to balance agricultural potential among crops. Potatoes are usually grown on the best land, but receive relatively infrequent irrigation. Wheat, the staple crop, occupies less fertile areas of the village, but is ensured abundant moisture. This trade off increases overall productivity, as potatoes are especially vulnerable to the ill effects of too much moisture. High soil moisture increases the risk of disease, decreases diurnal soil temperature variation which is necessary for high carbohydrate production, and may rot the developing tubers. Conversely, indigenous cereal crops are well adapted to local soil and radiation conditions, but benefit from increased water application. Beans receive water most frequently, and occupy the sunniest terraces. This may be an indication that farmers perceive them as a crop

TABLE 2

Crop growth potential: rankings of all measured inputs for all test plots

	Potato		Alfalfa			Orchard Past	Pasture	Pasture Bean			Wheat			Barley	
	#1	#2	#3	#1	#2	#3 #1	#1	#1	#1 #2 #3		#1	#2	#3	#1	
Sunshine Hours/Day	11	10	3	8	4	1	13	2	12	9	5	14	7	15	6
Aspect	9	2	11	9	15	11	6	8	7	5	13	2	1	4	13
Soil Temperature	7	5	2	6	11	1	14	3	15	12	13	9	10	4	8
Surface Temperature	8	5	2	3	10	1	14	5	15	13	9	12	11	7	4
Air Temperature	12	6	7	2	3	1	14	7	15	9	10	4	12	5	10
Altitude	3	4	11	2	12	15	7	14	5	6	10	9	1	13	8
Humidity	12	12	7	9	14	6	4	10	5	3	2	11	1	15	8
Evaporation	13	11	3	7	1	12	-	2	5	6	4	9	8	14	10
Slope	3	1	4	4	8	11	12	10	6	6	13	9	1	11	15
Plot Size	2	4	1	7	10	9	3	5	13	11	14	15	6	12	8
Distance From Nala	2	4	15	8	10	14	6	11	3	9	12	5	1	7	13
Water Holding Capacity of Soil	2	2	9	2	12	14	15	2	2	1	2	9	2	9	12
Nitrate	4	2	1	13	15	14	5	8	11	6	3	7	9	12	10
Phosphorus	1	1	1	1	1	1	13	14	10	1	1	10	1	14	12
Potassium	8	1	2	14	10	10	12	14	9	14	12	7	3	6	5
Calcium	5	4	8	15	5	5	12	9	3	9	11	1	12	2	12
Magnesium	9	7	10	14	14	7	1	10	3	10	10	1	3	3	3
Manganese	5	3	4	7	7	7	1	1	7	4	7	13	15	13	7
Aluminum	2	7	2	12	13	2	2	8	9	13	13	9	1	9	2
Sulfate	3	1	4	4	4	4	4	4	3	4	4	4	4	4	1
Iron	2	6	6	6	6	6	6	2	6	6	2	2	6	1	6
Organic Matter	13	3	5	1	1	9	3	11	8	5	10	15	12	5	14
pH	14	1	3	11	9	11	14	11	3	9	3	3	1	3	3
Irrigation Frequency (days)	8	10	10	13	13	20	7	7	6	6	6	6	7	7	6

Table 3

Crop growth potential: rankings of selected indicators for each crop category (based on measurements of the entire cultivated area)

	Potato		Alfalfa		Orchard P	Pasture	Bean			Wheat			Barley		
	#1	#2	#3	#1	#2	#3	#1	#1	#1 #2 #3		#3	#1	#2	#3	#1
Diurnal Heat Intensity (soil temperature)	7	5	2	6	11	1	14	3	15	12	13	9	10	4	8
Growing Season Duration (altitudinal variation)	3	4	11	2	12	15	7	14	5	6	10	9	1	13	8
Photosynthetic Potential (sunshine hours/day)	11	10	3	8	4	1	13	2	12	9	5	14	7	15	6
Water Temperature (distance from nala)	3	4	15	8	10	13	5	11	2	7	12	6	1	9	14
Water Utility (plot size)	2	4	1	7	10	9	3	5	13	11	14	15	6	12	8
Evaporation (plot evaporation)	13	11	3	7	1	12	-	2	5	6	4	9	8	14	10
Soil Quality (nitrate content)	4	2	1	13	15	14	5	8	11	6	3	7	9	12	10
Irrigation Frequency (days)	8	10	10	13	13	20	7	7	6	6	6	6	7	7	6

Table 4

Crop growth potential: rankings of selected indicators for each crop category (based on test plot measurements)

	Potato	Fodder	Bean	Cereal
Diurnal Heat Intensity (soil temperature)	1	2	4	3
Growing Season Duration (altitudinal variation)	1	4	2	3
Photosynthetic Potential (sunshine hours/day)	2	1	3	4
Water Temperature (distance from nala)	2	4	1	3
Water Utility (plot size)	1	2	4	3
Evaporation (plot evaporation)	3	2	1	4
Soil Quality (nitrate content)	1	4	3	2
Irrigation Frequency (days)	9.3	12	6	6.5

struggling to survive at the limits of its moisture and growing season range.

In addition to its direct effect on soil moisture, frequency of water application may be utilized as a means of altering other parameters of agricultural potential. Several findings support this assertion. First, a rough correlation exists between frequency of water application, and surface and soil temperature. Potatoes, which were irrigated least frequently, have the greatest soil, and second greatest surface temperatures. Alfalfa Plot 3 was watered only twice in 40 days; its soil and surface temperatures were substantially higher than other crops. Beans, which were irrigated most frequently, had the lowest soil and surface temperatures. The cooling effect of frequent water application is enhanced by the high albedo and dense crop cover of beans. Second, fields that were irrigated most frequently had greatest humidity readings. This relationship holds for all crops. Third, larger plots were watered more frequently than small plots. This may be because large plots are more difficult to water effectively. Larger plots commonly have steeper slopes, and always require water to travel over longer distances to reach all portions of the plot. Part of this relationship is explained by the crop itself: bean fields

TABLE 5

Crop growth potential: rankings of selected indicators for each crop category (based on measurements of the entire cultivated area)

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	Potato	Fodder	Bean	Cereal
Sunshine Hours/Day	4	3	1	2
Aspect	2	3	1	4
Altitude	1	4	2	3
Slope	1	4	2	3
Plot Size	1	4	2	3
Distance From Nala	2	4	1	3
Irrigation Frequency (days)	9.3	12	6	6.5

were largest and potato plots smallest, and beans require more moisture than do potatoes. Fourth, with the exception of potato fields, there is a rough relationship between decreasing distance from the meltwater stream and increasing frequency of water application. Those fields farther from the meltwater source are irrigated more often. This reflects farmers' concerns that cold, sediment laden water (i.e., close to the meltwater source) stresses crops. Potatoes require the nutritious soils of eastern slopes and the valley bottom, but not the benefit of frequent application of relatively warm and clean water. Finally, it is worth noting that there is no apparent correlation between frequency of water application and soil fertility. Any supplementary effect that meltwater sediment has upon soil fertility seems to be offset by leaching of nutrients through the soil.

The research reported here goes some way toward supporting the modest conclusions that the spatial distribution of crops in Holshal and Ghoshshal is related to the spatial distribution of micro-environmental conditions, and that farmers utilize their control over frequency of irrigation to alter the micro-environmental conditions of individual plots, in order to increase their agricultural potential for specific crops. However, these conclusions must be considered tentative in the absence of (a) more detailed statistical analysis of a larger sample of test plots, (b) an investigation of the combined effects of micro-environmental conditions on crop growth potential, and (c) some consideration of the role of local socio-cultural context on the relationship between crop distribution and micro-environmental conditions.

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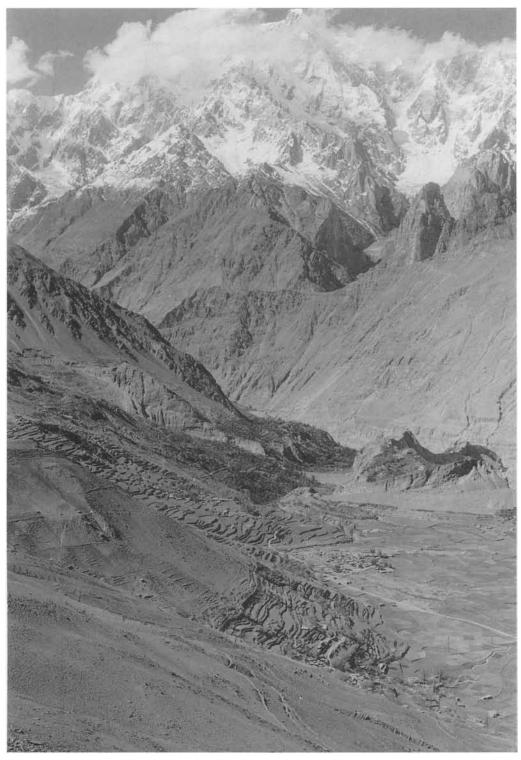
Readers who require more information on how inputs and indicators were chosen are invited to contact the author.

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The northern portion of Hopar Settlement, Gilgit District, Northern Areas, Pakistan. The community is flanked on the west (foreground) and north by pastured slopes, extending to 6,000 m, and on the south and east by the Bualter Glacier (barely visible, middle ground); the cultivated and terraced lands range from 2,500 to 3,000 m. Micro-environmental determinants of crop distribution in the two southerly villages of the settlement (Hoshal and Ghoshushal) are discussed by David Butz in this issue, pages 89–97. Photograph by David Butz.