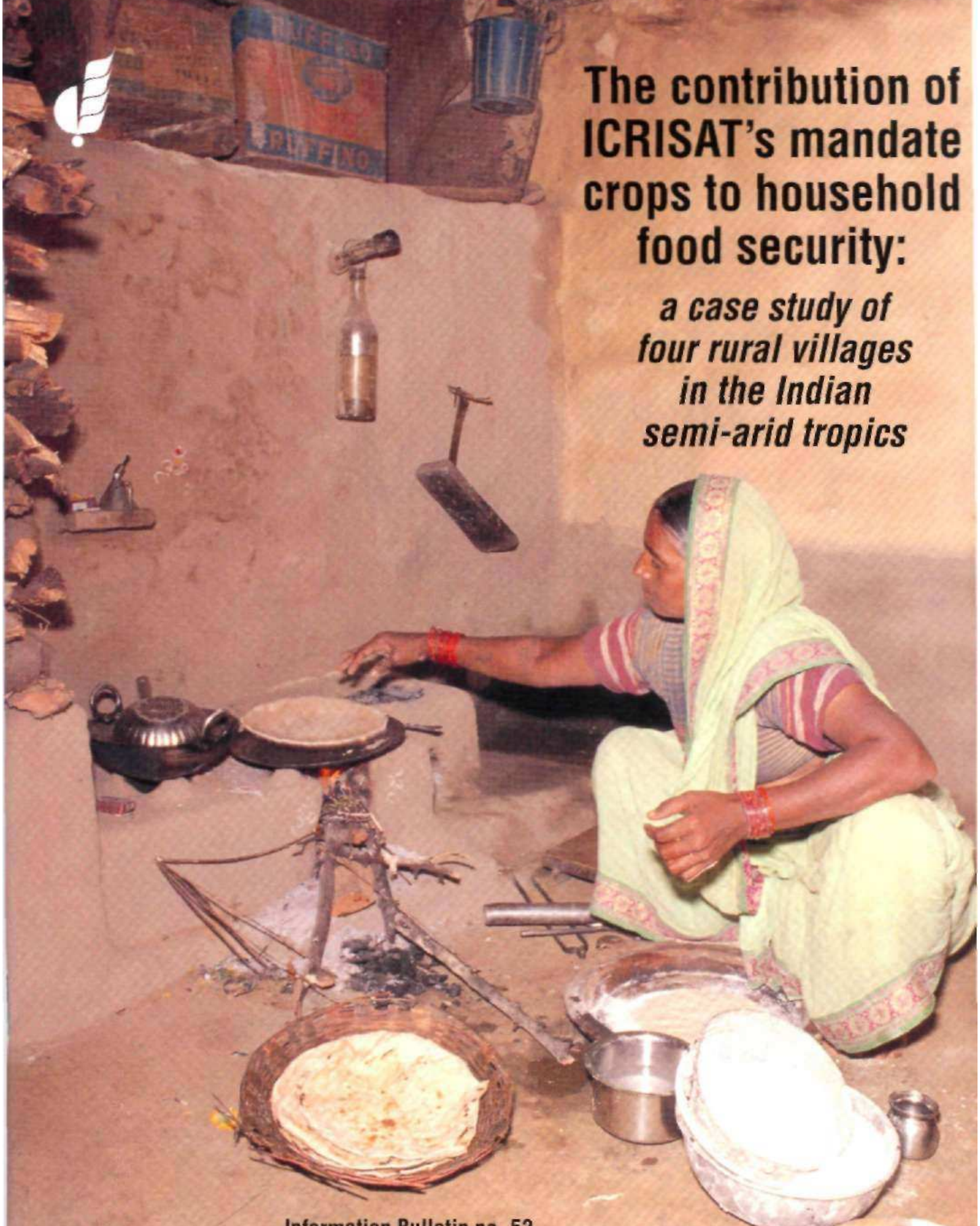

The contribution of ICRISAT's mandate crops to household food security:

a case study of four rural villages in the Indian semi-arid tropics

Information Bulletin no. 52
International Crops Research Institute for the Semi-Arid Tropics

Citation: Chung, K.R. 1998. The contribution of ICRISAT's mandate crops to household food security: a case study of four rural villages in the Indian semi-arid tropics. Information Bulletin no. 52. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 40 pp. ISBN 92-9066-390-1. Order code: IBE 052

Abstract

The conceptual linkage between increased food production and improved nutritional status appears straightforward; yet, devising research strategies that lead to real change has proved difficult. Although intra-household resource allocations are a strong determinant of individual nutritional status, this bulletin focuses on the possibilities for technical change to improve consumption at the household level. The reported study therefore seeks to update knowledge of the role that the International Crops Research Institute for the Semi Arid-Tropics (ICRISAT) mandate crops play in the diets of the rural poor. Specifically, it examines the state of undernutrition in the study area, the dependence of the rural poor on ICRISAT's mandate crops, the actions available for improving the diets of the rural poor, and the role agricultural research should play in the fight to reduce undernutrition. These topics are addressed through a household-level analysis of dietary patterns in four rural villages in the semi-arid tropics (SAT). The ultimate purpose is to discuss the menu of options available to researchers interested in strengthening the link between agricultural technology and nutritional well-being. The analysis focuses on identifying current dietary and expenditure patterns in two regions within the Indian SAT.

The author

Kimberly Chung is presently Assistant Professor of Research at The Watson Institute for International Studies and the Department of Community Health at Brown University, Providence, RI 02912, USA, This publication was drafted while the author was a Scientist with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The author gratefully acknowledges Howarth Bouis for providing the framework for analysis, and Tim Kelley and John Kerr for their careful reviews.

Partial support for the analysis reported
in this publication was provided by

The Ford Foundation

The contribution of ICRISAT's mandate crops to household food security: a case study of four rural villages in the Indian semi-arid tropics

K R Chung

Information Bulletin no. 52

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

1998

Contents

I. Introduction

During the 1970s, technical change resulting from agricultural research had a dramatic effect on aggregate food supplies in many developing countries (Hazell and Ramasamy 1991). As a result the concept of technical change is frequently linked to the goal of ending undernutrition (Pinstrup-Anderson and Jaramillo 1991, Pinstrup-Anderson and Hazell 1987, Pinstrup-Anderson et al. 1984, Staatz and Bernsten 1992). Now, more than two decades later, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) still considers its core mission to be the development of agricultural technologies that bring greater wealth and improved food security to those living in the semi-arid tropics (SAT). Agroclimatically the SAT includes the tropical areas of the world where rainfall exceeds potential evaporation during 4 to 6 months of the year. Large parts of India including much of Andhra Pradesh, Rajasthan, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, and Uttar Pradesh are classified as semi-arid (Walker and Ryan 1990). Mean annual rainfall in the SAT ranges from about 400 to 1 200 millimeters per year.

ICRISAT's mission therefore focuses on improving agricultural productivity of six "mandate crops" (sorghum, pearl millet, finger millet, groundnut, chickpea, and pigeonpea) that have long been components of semi-arid agricultural systems around the world. The ability of these crops to adjust to harsh climates and poor soil conditions have caused them to be widely grown in resource-poor areas. As such, they are often termed "poor man's crops."

The conceptual linkage between increased food production and improved nutritional status appears straightforward; yet, devising research strategies that lead to real change has proved difficult. Figure 1 shows the linkages betwee technical change, increased household food consumption, and individual nutritional status. The upper box shows the relationship between technical change and household food consumption. The lower box broadens this notion to include individuals within the household. Although intra-household resource allocations are a strong determinant of individual nutritional status, this bulletin focuses on the possibilities for technical change to improve consumption at the household level. Intra-household issues, although important, are beyond its scope.

Technical change is proposed to positively impact household food consumption through one of three channels: (1) by increasing household income, (2) by lowering food prices, or (3) by altering time allocation patterns (Mebrahtu et al. 1995). Effecting change in any one of these factors, however, may not be enough to elicit significant changes in household food consumption. Rather, researchers must have a keen understanding of current dietary patterns and the way that consumers react to changes in income, price, and time demands. Only then can well-informed strategies for agricultural research be formulated.

It was for this reason that ICRISAT began to examine dietary patterns in the SAT (Ryan et al. 1974). Between 1976 and 1978, ICRISAT undertook a large dietary study as part of an effort to prioritize plant breeding activities for improving human nutrition (Ryan et al. 1984). At this time, the academic community debated the relative importance of protein and energy malnutrition. ICRISAT was therefore faced with a major question regarding its breeding strategy: should breeding efforts focus on improving the quality of protein contained in the mandate crops, or should they focus on the traditional area of yield enhancement? Early studies on nutritional patterns indicated that diets in the study area were highly deficient in energy and several micronutrients, but less so in protein and essential amino acids (Ryan et al. 1984). Researchers found select cases of lysine deficiency in the study area, but surmized that greater efforts should be placed on increasing the "size" of the existing diet,

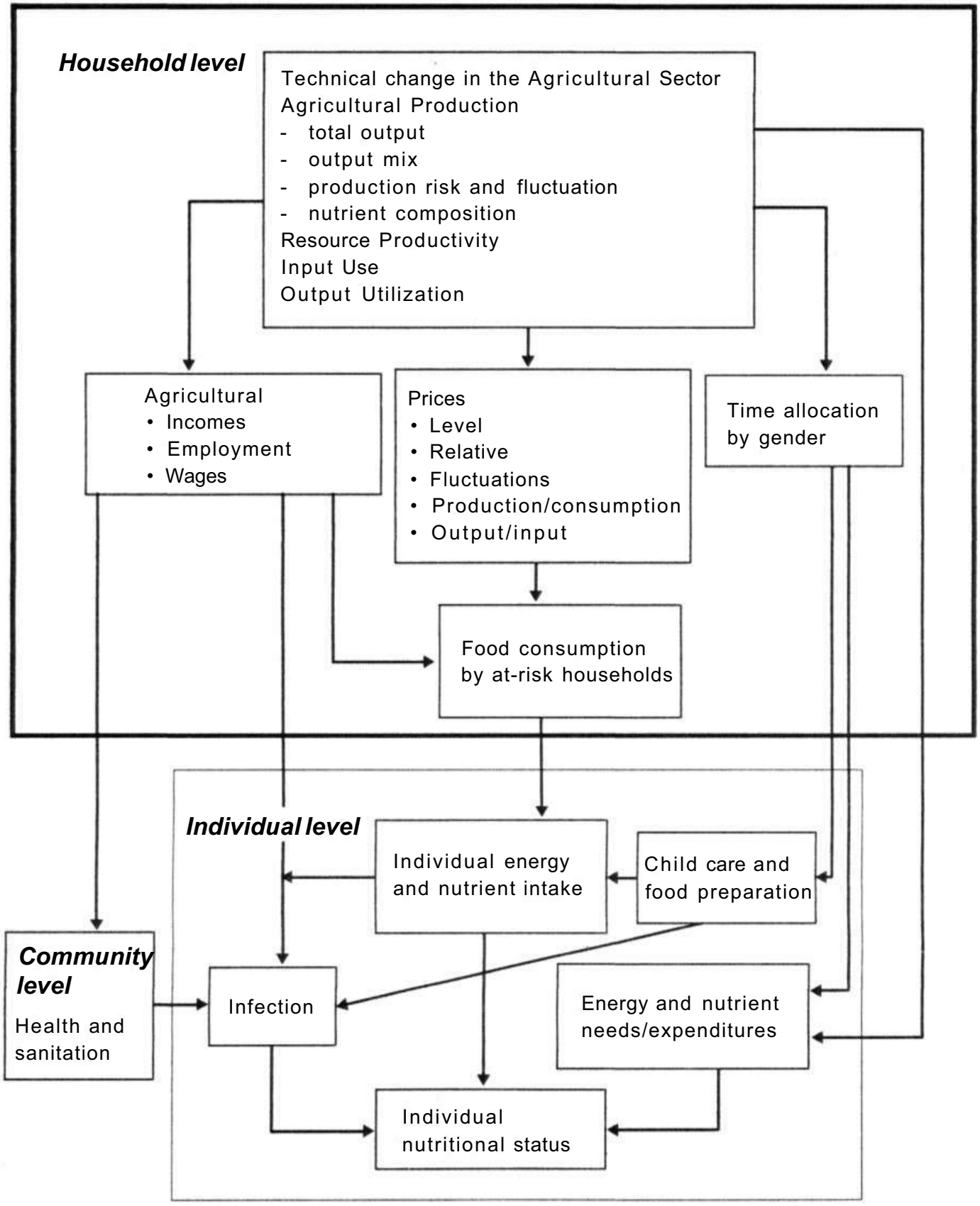

Figure 1. Overview of links between technical change in agriculture and nutrition (adapted from Mebrahtu et al. 1995)

rather than on altering the ammo-acid content of any mandate crop. They therefore recommended that research efforts focus on improving yields rather than on improving protein quality. Researchers maintained that ICRISAT's greatest contribution to decreasing undernutrition in the SAT would be through improving yield and yield stability through advancements in insect and disease resistance and/or tolerance.

ICRISAT has largely followed this research agenda during the past 15 years. However, during these years changes in cropping patterns have led to a dramatic decline in the area sown to coarse grains and cereal crops (Kelley et al. 1995). These trends in cropping patterns suggest that consumption behavior and dietary patterns may have also changed. As such, it is prudent for ICRISAT to re-examine its nutrition-related priorities for technology development.

This study therefore seeks to update our knowledge of the role that ICRISAT's mandate crops play in the diets of the rural poor. Specifically, it asks: what is the state of undernutrition in this study area in the Indian SAT? How dependent are the rural poor on ICRISAT's mandate crops? What actions are available today for improving the diets of the rural poor? And finally what role should agricultural research play in this fight to reduce undernutrition?

These questions are addressed through a household-level analysis of dietary patterns in four rural villages in the SAT. The data used for this study were collected in 1992/93 in four villages that were studied intensively between 1975 and 1984 as part of ICRISAT's Village Level Studies (VLS). The ultimate purpose of this paper is to discuss the menu of options available to researchers interested in strengthening the link between agricultural technology and nutritional well-being. As such, the analysis focuses on identifying current dietary and expenditure patterns in two regions within the Indian SAT Section II begins with a description of the study setting and data-collection methods. Section III presents an overview of current diet and expenditure patterns at the household level. Section IV reviews current levels of nutritional adequacy in the study households. Section V examines food expenditure trends. Sections VI and VII identify the contribution made by the mandate crops to the intake of energy, and two major micronutrients, iron and vitamin A. Section VIII presents an examination of seasonality dimensions. Section IX briefly discusses dietary protein. And, finally, Section X concludes with policy options available to improve nutritional well-being and the specific role that technology development may play in this endeavor.

II. Data used for analysis

Household surveys

The data used in the analysis were collected in 1992/93 for the purpose of identifying indicators of food and nutrition security in the Indian SAT (see Chung 1995 for details of study design and results). The four villages chosen for study were among those studied previously by ICRISAT in its VLS. These villages have been the subject of many studies and are well documented by Walker and Ryan (1990).

Sample

At the time the study began there was already a wealth of information on the VLS households. The 1992/93 sample was therefore chosen to achieve a number of objectives (Haddad et al. 1995). First, the sample included as many former VLS households as possible to maximize the possibility of future intergenerational analyses. Second, for logistic reasons data collection was limited to four of the previously studied VLS villages. Of the 10 possible VLS villages four had been studied in detail and a time series of data had been collected for each; these villages were therefore chosen for follow up. Within each chosen village all households that participated in the 1975-84 VLS study (the "old" VLS study) were included in the sample.

New families that had separated from the original VLS households were also included. In addition, all households from the second 1989/90 study (the ''new" VLS study) were included. Finally, some "non-VLS" households were included to ensure at least 80 households in each village. The non-VLS households were chosen from a census of landless and smallholder families that had at least two preschool children. Only 11 non-VLS households were included in the sample. In total, 328 households were surveyed during the study with 309 households present in all rounds. Data for these 309 households are used for the analyses reported here.

Location

The four study villages, Dokur, Aurepalle, Shirapur, and Kanzara are located in the semi-arid zone of south-central India in two states. Dokur and Aurepalle are located in the dry, inland, Telangana area of Mahabubnagar district in Andhra Pradesh state. Shirapur is located in the Bombay Deccan in Sholapur district of Maharashtra state and Kanzara is located in the rain-assured Akola district of Maharashtra. The village economies are based on rainfed agriculture, but rainfall is generally lower in Sholapur and Mahabubnagar (Walker and Ryan 1990) than in Akola.

Aurepalle, the VLS village that was once worst-off economically (Walker and Ryan 1990) is situated in an area that is prone to droughts. Most farming is dryland and the soils are predominantly red Alfisols. The increasing demand for two rural products, toddy (local liquor) and sheep, has diversified the economy beyond crop production. The effect has been to make many of the landless relatively well off; many have done well enough to acquire land. Farming continues to be the major occupation, however, with the majority of plots still rainfed. The Alfisols have poor water-holding capacity; hence, the busiest agricultural season occurs during the kharif, or rainy season. During the postrainy (rabi) and summer seasons irrigated rice is also grown but a far smaller area is sown during these times than in the rainy season. Diets are rice-based and supplemented by sorghum. A statewide public distribution scheme provides rationed rice at subsidized rates. The entitlement is not sufficient for most households and must be supplemented by market or in-kind supplies of rice and sorghum. Although vegetables are not grown for commercial sale, a few women from nearby villages come to Aurepalle to sell vegetables door to door. Fruit is not sold in the village. Most villagers do not make the journey to Amangal (10 km away by bus) where fruit and vegetables are regularly sold.

Dokur, like Aurepalle, is situated in Mahabubnagar district, but is significantly different in one respect. In Dokur most of the land is irrigated from a local irrigation pond. The effect of irrigation is clear; when the tank fills rice is grown in three seasons and there are greater opportunities for slack season employment. When the tank does not fill more land is sown to sorghum. Like Aurepalle, the diet is rice-based and subsidized rice is rationed on a monthly basis. Sorghum is used to supplement the diet, particularly as rice prices rise through the postrainy and summer seasons. Fruit and vegetables are not sold in the village and villagers must travel to Deovarkarda (7 km) to purchase them. Few households make the journey, however, as public transport is not available.

Shirapur is situated in an area characterized by deep-black clay soils (Vertisols), erratic rainfall, and frequent droughts. The village economy is heavily dependent on local crop production, but the cropping cycle is very different from that found in the other study villages. More specifically, the Vertisols in Shirapur are capable of retaining moisture. Farmers therefore minimize the risk associated with erratic rainfall by foregoing the rainy season. They instead allow the soils to collect as much moisture as possible in preparation for a postrainy season sowing. The postrainy season

is therefore the main cropping season in this village. During the other seasons much of the land lies fallow and employment is low. A government employment scheme (the Employment Guarantee Scheme, EGS) provides work for villagers, but demand for labor is both inconsistent and insufficient to employ all who need work. Diets in Shirapur, as in most of Maharashtra, are sorghum-based with rice eaten infrequently. Vegetables are grown and sold in the village throughout the year. Strangely enough, the year-round availability of vegetables reflects the general lack of profitable alternatives for land during the off-seasons. More specifically, irrigation water is so scarce in the summer season that there is only enough water to cultivate small patches of vegetables near the wells. These vegetables are sold daily in the village center and are consumed widely. Few fruits are sold in the village. Transportation to the nearest market in Mohol (11 km) is difficult and expensive. Few households use the Mohol market to purchase foods that are not available in the village.

Finally, Kanzara is located in a rainfall-assured area of Akola district. The area is characterized by medium-deep black clay soils. Because rainfall is assured dryland farming is less risky here. For smallholder farmers and laborers ample employment is usually available during the rainy season. During the postrainy season farming is also fairly active when canal water is available. Kanzara, however, is situated at the end of the canal, so irrigation is not completely assured. Neighboring villages that have greater access to canal water provide backup opportunities for employment in the rainy and summer seasons. Diets in Kanzara are sorghum-based, but are complemented by frequent wheat consumption. Many legume crops are grown in the village and they have become a common feature of the Kanzaran diet. The village is very close to a small town called Murtizipur and transportation is quite convenient. As a result, villagers commonly attend the market to buy vegetables and fruit.

Data collection methods

Both economic and nutrition surveys were conducted for this study. Table 1 shows the various modules collected in each village. The data were collected in three rounds during the 1992/93 agricultural year. The first round occurred between Aug and Nov 1992 and coincided with the rainy season. The second round occurred between Jan and Mar 1993 and coincided with the postrainy season. The final round took place between Jun and Aug 1993 and represented the late summer and early monsoon season. Table 2 shows the timing of each survey round.

The data collection methods are detailed in Chung (1995). For the sake of brevity, only modules 10 and 11 are discussed here, i.e., the household expenditures and 24-hour diet survey modules. For this study, 24-hour recall diet surveys were used to construct nutrient adequacy ratios. Six diet surveys were conducted during three rounds of data collection for each household. To provide repeated measures of dietary intakes two dietary recalls were collected during each round. These surveys identified 127 different foods consumed by the sample households. Conversion factors provided by the National Institute of Nutrition (Gopalan et al. 1994) were used to convert each food into its nutrient equivalent of energy, protein, fat, calcium, carotene, vitamin C, niacin, riboflavin, thiamin, and iron. Recipes for each preparation consumed during the preceding 24-hour period were collected and the quantity of each food ingredient was multiplied by the appropriate nutrient conversion. The total amount of each nutrient consumed by the household was obtained by summing the nutrient contribution across all ingredients identified during the diet survey.

To obtain a measure of dietary adequacy at the household level, the dietary requirement for each individual in the household was expressed in terms of "adult equivalents." The number of adult equivalents for an individual is the nutrient requirement (as determined by

Table 1. Survey information collected from Dokur, Kanzara, Aurepaile, and Shirapur during the alternative Indicators study.

Number and names of modules		Respondents
1	Household roster	All households in the sample
2	Migration	All households in the sample
3	Education	All households in the sample
4	Occupation	All households in the sample
5	Housing	All households in the sample
6	Land	All households in the sample
7	Income generating assets and cropping	All households in the sample
8	Durables	All households in the sample
9	Credit	All households in the sample
10	Expenditure	All households in the sample
11	Dietary recalls	All individuals
12	Food frequency	All women; children < 6 years
13	Anthropometry	All women; children < 6 years, all males once[1]
14	Morbidity	All females > 10 years; all children < 6 years
15	Breast feeding	All mothers of partially or completely breast-fed children
16	Reproductive history	All females married or engaged
17	Vitamin A food frequency	All children < 6 years; mother of the child

1. Information collected from all individuals in Aurepaile and Shirapur.

Table 2. Timing of the three survey rounds in the four study villages.

	1992					1993						
Village	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Aurepalle												
Round			1					2				3
Typical food availability			surplus					medium				low
Season			rainy					postrainy				summer
Dokur												
Round	1					2					3	
Typical food availability	low					surplus					low	
Season	rainy					postrainy					summer	
Shirapur												
Round			1				2					3
Typical food availability			low				surplus					low
Season			rainy				postrainy					summer
Kanzara												
Round		1				2					3	
Typical food availability		medium				peak					medium	
Season		rainy				postrainy					summer	

the individual's age, sex, and physiological status) divided by the requirement for a "reference person". Among the academic nutrition community in India, the reference person is usually taken to be a 60-kg man of moderate activity (Indian Council of Medical Research 1994). Summing the total nutrient intake by the household and dividing it by the number of adult equivalents gives a measure of household nutritional adequacy. This measure allows researchers to compare nutrient adequacies among households of different sizes and compositions.

To obtain measures of total household expenditure and total household food expenditure respondents were asked to recall expenditures (by item) during the past season. A variable time-period recall method was used. The expenditure questionnaire requested the quantity purchased, the price of the item, the frequency of purchase, and the source of the acquisition. The total expenditure was calculated for each item and converted to a weekly expenditure figure. Expenses for all food items were summed to obtain the weekly household food expenditure for that season. Expenses for all non-food items were summed in the same way. Total weekly household expenditures were obtained by summing food and non-food expenditures.

III. An overview of household dietary and expenditure patterns

Table 3 presents an overview of dietary and food expenditure patterns for the study households. Mean per capita expenditures, the household share of the food budget, and household energy intake (as measured by 24-hour recall) are shown by income group, caste group, and village. Throughout this study total household expenditure is used as a proxy for household income. This decision is based on results from previous VLS research that indicated that; (1) consumption expenditure is substantially less volatile than household income, and (2) nutrient intake is better predicted by expenditures than income (Walker and Ryan 1990). Two findings are notable.

Firstly, Table 3 suggests that consumption behavior varies substantially among the four sample villages. The mean levels of energy intake, for example, vary between 2020 kilocalories and 2405 kilocalories. The largest differences, however, fall out around state lines. Table 3 indicates that the mean household energy intakes for the two Andhra villages are substantially higher than those displayed in the Maharashtra villages; on the whole, Andhrans appear to consume approximately 400 calories per adult equivalent more than the Maharashtrians. This difference (however large and surprising) is similarly documented by the National Nutrition Monitoring Board (NNMB) in their most recent Ten-State Survey conducted in 1990/91 (NNMB 1993). The NNMB surveyed 799 households across Andhra Pradesh and 578 households in Maharashtra and found a 400 calorie difference per adult equivalent between the two states.

The NNMB document uses the 60-kg adult male doing sedentary work as the "reference person" in the calculation of adult equivalents. 2350 is the energy requirement for this reference person. The calculations performed in this study follow the example given by ICMR (1994) and use a 60-kg adult male doing moderate work as the "reference person." 2875 is the energy requirement for this standard. To compare the NNMB results to those obtained in this study the energy values found in Table 3 of NNMB (1993) need to be multiplied by the factor 2875/2350 to arrive at an average energy intake that uses comparable adult equivalent measures. NNMB (1993) reports a difference in average energy intake between Maharashtra and Andhra Pradesh to be 325 kcals, assuming a sedentary reference person. To compare the difference with that shown in Table 3 multiply 325 kcals by (2875/2350), to obtain 397 kcals.

Higher caloric diets therefore appear to be a characteristic feature of the Andhra diet and not an artifact of data collection. These energy differences 'by location' are substantial and suggest important differences in consumption behavior between the two areas. Thus the term location' is used to describe the geographic subsets used for this study. The four villages were therefore divided according to the states in which they are located. The term 'state' has been avoided as it is felt to imply that a (statistically representative) statewide survey was conducted.

Secondly although household energy intake differs between locations, Table 3 indicates that energy does not increase monotonically with income. Rather, per capita energy intakes appear invariant to income, even though per capita food expenditures rise monotonically with income. This finding is consistent with income-nutrient relationships identified in the late 1970s by Ryan et al. (1984). Using regression analysis to study the determinants of nutritional status, Ryan et al. found that the link between energy intake data and income was tenuous. Although counter-intuitive at the time, this finding is now consistent with the revisionist view of energy-income relationships. The revisionists argue that energy consumption is much less responsive to income than the consensus perception of a decade ago (Behrman 1995). Citing that a number of data

Table 3. Per capita total expenditures, per capita food expenditure, household shares of food budget, and household energy intakes, by total expenditure quartile, caste group, and village.

	Per capita total expenditure[1,2] (Rupees week^{-1})	Per capita total food expenditure[1,2] (Rupees week^{-1})	Share of food in household budget (Percentage of total expenditure)	Household energy intake[3] (kcals, adult equivalent^{-1}, day^{-1})
Expenditure quartile[4]				
1	29.5	22.64	75.5	2 092
2	42.3	32.0	76.1	2 334
3	53.5	38.6	73.1	2 194
4	86.3	55.6	68.3	2 271
All	52.8	37.2	73.2	2 221
Caste group				
Scheduled caste/tribe	42.0	30.7	74.5	2 269
Backward class	49.3	36.0	74.4	2 266
Forward class	68.0	44.5	69.9	2 095
Village				
Aurepalle	57.6	40.5	74.7	2 389
Dokur	44.6	29.9	68.7	2 405
Shirapur	68.6	49.7	74.3	2 020
Kanzara	40.6	28.7	75.4	2 089

1. Per capita, derived from food expenditures.
2. In 1992/931 US$ was valued at 30 Indian rupees (Rs).
3. Per adult-equivalent, derived from 24-hour recall of foods consumed.
4. Quartile 1 is the lowest rank and 4 is the highest.

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

collection and estimation issues are responsible for inflated energy-income elasticities, the revisionists maintain that the true elasticities are much lower than previously perceived, perhaps even less than 0.1 (Bouis and Haddad 1992). Bouis interprets these elasticities to mean that low-income households give paramount importance to maintaining a threshold level of energy intake (Bouis 1996). In addition, as income rises, households purchase more expensive sources of energy; hence, energy intake may rise proportionately less than total food expenditures (Behrman 1995).

IV. Current status of nutritional intake in Maharashtra and Andhra Pradesh study villages

To describe the nutritional status of the study population the nutrient adequacies in the two study areas are briefly discussed. Table 4 shows the mean nutrient adequacy for 10 essential nutrients by location of village. Adequacy ratios are also given for the Ten-State Study published by the NNMB (NNMB 1993) for comparison. Adequacy figures are similar to the NNMB averages in Maharashtra, the only exceptions being iron and calcium. With

Table 4. Nutrient adequacy ratios by location and expenditure tercile.

	Expenditure tercile				
Nutrient	1	2	3	All	State average[1]
Maharashtra villages					
Energy	71	70	74	71	67
Carotene	35	43	57	44	34
Iron	62	61	64	62	93
Vitamin C	37	46	58	47	53
Protein	94	96	98	96	93
Fat	103	113	156	124	141
Niacin	91	94	106	97	80
Riboflavin	48	48	51	49	50
Thiamine	136	131	137	135	133
Calcium	50	59	75	61	97
Andhra Pradesh villages					
Energy	82	86	84	83	78
Carotene	20	27	23	23	39
Iron	29	36	31	32	89
Vitamin C	42	49	58	49	77
Protein	81	86	82	83	98
Fat	60	71	95	75	112
Niacin	73	78	74	75	72
Riboflavin	36	39	40	38	43
Thiamine	55	64	61	60	64
Calcium	44	52	63	53	112

1. Source: NNMB 1993.

the Andhra villages, however, adequacy ratios are substantially different for iron, vitamin C, fat, and calcium. These differences are likely due to the fact that the NNMB study also includes districts from coastal Andhra. Dietary patterns in the coastal areas are known to be more diverse than in the inland dryland areas; hence the difference in adequacy ratios reflects these differences. These differences also indicate that the trends shown for the Andhra villages in this study should not be regarded as representative of Andhra Pradesh as a whole. Rather they should be regarded as representative of the inland Telangana areas of the state where the study was conducted.

Each of these ten nutrients is essential for child growth and health maintenance. Yet, energy, iron and vitamin A are of particular interest in South Asia due to the prevalence of low intakes and the debilitating effects of these nutrient deficiencies. Energy, of course, is related to proper growth and development in children and is necessary for building muscle mass and undertaking physical labor. Low intakes of vitamin A lead to progressive eye damage and irreversible blindness. Indian diets are relatively devoid of pre-formed vitamin A. Low iron intakes are directly associated with anemia, but are also weakly associated with impaired child development, reduced work capacity, and diminished learning ability (ACC/SCN 1992). The analysis follows the NIN convention in expressing vitamin A in terms of micrograms of carotene rather than retinol equivalents. Hereafter, vitamin A intake is expressed in terms of micrograms of carotene.

Two interesting points emerge from Table 4. Firstly, nutrient adequacies are low for almost all nutrients shown. Energy intake is certainly deficient at both locations, but adequacy levels for the micronutrients reflect even greater deficiencies. The largest deficiencies exist for carotene, vitamin C, riboflavin, and iron. Carotene and iron intakes are particularly low in the study areas. On average, households in Maharashtra function at 44% adequacy of carotene requirements, while those in Andhra are functioning at only 23% of requirements. Intakes of iron are also very low, although those in Maharashtra (62%) are almost twice those in Andhra Pradesh (32%).

Table 4 illustrates that iron and carotene adequacy levels are extremely low in the Andhra villages. Furthermore, increases in income appear to have no effect on these chronically low levels of iron and carotene intake. Table 4 also shows that iron adequacy is low in Maharashtra and does not appear to be responsive to improvements in income. Carotene adequacy levels are also low, but carotene undernutrition appears to decrease as income levels rise.

Secondly, Table 4 indicates that nutrients that are income-sensitive tend to be distributed more densely in non-staple foods (dairy products, fruits, and vegetables). By contrast, nutrients that are distributed more densely in staple foods are income-invariant. In Maharashtra, for example, energy, iron, thiamin, and niacin adequacies do not appear to have any relation to income; protein appears to be only slightly correlated with income. By contrast, carotene, fat, calcium and vitamin C adequacies rise with increasing income. These nutrients are present in very low levels in cereals and pulses, but are more abundant in fruits, vegetables, or dairy products. In the Andhra Pradesh villages, energy, iron, protein, and niacin adequacies are unrelated to income changes, but vitamin C, fat, and calcium adequacies are. Carotene, however, appears invariant to changes in income. This pattern of findings suggests that households seek to improve the quality and diversity of their diet as incomes rise, rather than merely increasing the quantity of staple foods in their diet. In addition, the responsiveness of different nutrients to income at the two locations underscores the proposition that consumption patterns differ substantially in these two areas.

The pattern of nutrient adequacies shown in Table 4 represents long-standing dietary habits

in these areas. Table 5 compares the adequacies observed in 1992/93 to those derived from data collected from the same villages in 1977/78. The comparison between the time periods indicates that nutrient adequacies have generally risen over time. Nevertheless, the increases have been small for almost every nutrient. In addition, adequacies for micronutrients show a pattern of being persistently low. For example, in 1977/78 carotene adequacy levels were only 11% of recommended levels in Andhra Pradesh and 17% in Maharashtra. Fifteen years later, they continue to fall far below recommended levels in 1992/93. The same is true for vitamin C, riboflavin, iron, and calcium. Finally, the pattern of differences between two study areas has also remained consistent through time. Maharashtrian diets tend to be lower in energy, but higher in all other nutrients, particularly thiamin and fat. Andhra diets, by contrast, appear to be very poor providers of almost all nutrients, but relatively high in overall energy.

Table 5. A comparison of nutrient adequacy ratios in 1977/78 and in 1992/93.

	Andhra Pradesh villages		Maharastra villages	
	1977/78[1]	1992/93[2]	1977/78[1]	1992/93[2]
Energy	77	83	66	71
Carotene	11	23	17	44
Iron	31	32	53	62
Vitamin C	32	49	16	47
Protein	79	83	84	96
Fat	58	75	104	124
Niacin	74	75	87	97
Rboflavin	36	38	39	49
Thiamine	60	60	123	135
Calcium	43	53	58	61

1. ICRISAT VLS dietary survey 1977/78.
2. ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

V. Effect of energy, diversity, and specific tastes on food expenditure patterns

Tables 6, 7, and 8 describe food expenditure patterns in the study villages. These tables are used to identify food groups that are responsible for the changes in adequacy illustrated in the previous section. Per capita food expenditures are shown in Table 6 by location, expenditure tercile, and food source. At both locations, overall per capita food expenditures rise monotonically with income, with wealthier families in tercile three spending 21-24% more on food than households in tercile one. In the Maharashtra villages per capita food expenditures rise most rapidly on milk (118%), rice (79%), sorghum (77%), groundnut (203%), and green leafy vegetables (208%). In Andhra Pradesh expenditures rise rapidly on milk (127%). In both areas marginal increases are also observed in "other vegetables", but the percentage increases are comparatively small.

Tables 7 and 8 disaggregate expenditures into per capita quantity consumed and price paid per kilogram. Two sets of consumption changes are evident as incomes rise; (1) households choose to increase the quality of foods that are "basic" to the local diet, and (2) households choose to increase the quantity of foods that add diversity to the diet. For example, assuming that price differentials represent quality differentials, Table 7 indicates that households opt to consume increasingly more-expensive, higher-quality staple foods as incomes rise. In Maharashtra, for example, households in higher-expenditure categories tend to purchase higher-quality sorghum and pulses, two basic components of the local diet. Similarly, in Andhra Pradesh, households tend to consume higher-quality rice, although the effect is much smaller than in the Maharashtrian villages. Table 8 reveals that households also choose to increase per capita consumption of foods that add diversity to their diets. For example, at both locations, households increase their per capita quantity of milk products consumed. Note, however, that the quality of milk products purchased (as revealed by Table 7) appears to remain the same.

Table 6. Per capita food expenditure (Rs. capita^{-1} week^{-1}) by expenditure tercile and food group.

Food group	Expenditure tercile 1	2	3	All
Maharashtra villages				
Rice	0.53	0.83	0.95	0.77
Sorghum	4.90	7.63	8.65	7.06
Pearl millet	0.11	0	0.08	0.10
Finger millet	0	0	0	0
Groundnut	1.52	2.32	4.61	2.82
Pigeonpea	1.83	2.10	1.82	1.92
Chickpea	0.41	0.38	0.36	0.39
Wheat	2.72	1.14	0.46	1.44
Maize	0.10	0.32	0.56	0.33
Non-mandate legumes	0.90	0.73	0.61	0.75
Milk/milk products	1.69	2.85	3.68	2.74
Meat/fish/eggs	0.63	0.48	0.50	0.54
Other vegetables	0.93	0.98	1.24	1.04
Fruit	0.53	0.43	0.29	0.41
Sugar/spices	2.37	2.15	2.07	2.20
Other oilseeds	2.45	1.80	1.02	1.75
Green leafy vegetables	0.12	0.24	0.37	0.25
Processed cereal foods	0.77	0.61	0.63	0.67
All mandate cereals	5.01	7.63	8.73	7.16
All mandate legumes	3.76	4.80	6.79	5.12
All	22.52	24.99	27.90	25.14
Andhra Pradesh villages				
Rice	12.97	13.29	13.16	13.14
Sorghum	1.17	1.37	1.29	1.27
Pearl millet	0.07	0.26	0.22	0.18
Finger millet	0.03	0.07	0.01	0.03
Groundnut	1.50	1.72	2.30	1.84
Pigeonpea	0.81	0.86	0.95	0.87
Chickpea	0.05	0.07	0.11	0.08
Wheat	0.03	0.18	0.10	0.10
Maize	0	0	0	0
Non-mandate legumes	0.11	0.15	0.21	0.16
Milk/milk products	1.83	2.12	4.15	2.70
Meat/fish/eggs	0.48	0.75	0.69	0.64
Other vegetables	1.52	1.69	1.72	1.64
Fruit	0.05	0.38	0.12	0.18
Sugar/spices	0.96	0.96	1.20	1.04
Other oilseeds	0.19	0.22	0.22	0.21
Green leafy vegetables	0.18	0.15	0.19	0.17
Processed cereal foods	0.70	1.08	0.71	0.83
All mandate cereals	1.27	1.69	1.51	1.49
All mandate legumes	2.36	2.66	3.36	2.79
All	22.65	25.31	27.34	25.10

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

Table 7. Food prices (Rs. kg^{-1}) by expenditure tercile and food group.

	Expenditure tercile			
Food group	1	2	3	All
Maharashtra villages				
Rice	6.51	6.16	6.03	6.19
Sorghum	3.24	4.23	4.82	4.14
Pearl millet	4.15	0	3.63	3.92
Finger millet	0	0	0	0
Groundnut	27.96	24.26	24.79	25.15
Pigeonpea	14.33	14.54	17.46	15.28
Chickpea	10.90	11.69	13.00	11.75
Wheat	4.46	3.50	1.14	3.23
Maize	3.86	4.09	4.09	4.07
Non-mandate legumes	9.87	11.78	15.88	11.69
Milk/milk products	8.49	7.56	7.40	7.67
Meat/fish/eggs	36.76	33.06	32.00	34.05
Other vegetables	3.49	3.71	3.87	3.70
Fruit	6.10	6.14	4.24	5.50
Sugar/spices	8.75	8.93	9.18	8.94
Other oilseeds	37.30	37.86	40.02	38.00
Green leafy vegetables	2.87	3.02	2.80	2.88
Processed cereal foods	15.52	16.50	18.61	16.69
All mandate cereals	3.25	4.23	4.80	4.09
All mandate legumes	17.10	17.60	21.30	18.67
All	6.31	6.56	6.67	6.51
Andhra Pradesh villages				
Rice	4.77	4.89	4.97	4.88
Sorghum	3.04	3.03	3.05	3.04
Pearl millet	2.89	2.91	2.81	2.87
Finger millet	2.65	2.28	1.54	2.24
Groundnut	31.95	31.50	30.70	31.29
Pigeonpea	17.44	17.43	17.53	17.47
Chickpea	11.83	12.19	11.36	11.71
Wheat	7.21	7.38	7.32	7.34
Maize	0.00	0.00	0.00	0.00
Non-mandate legumes	8.88	10.70	9.48	9.69
Milk/milk products	4.97	5.06	4.93	4.97
Meat/fish/eggs	17.03	20.30	20.78	19.52
Other vegetables	3.51	3.16	3.16	3.26
Fruit	4.14	8.11	4.74	6.51
Sugar/spices	9.43	9.23	8.81	9.13
Other oilseeds	31.44	31.11	34.15	32.19
Green leafy vegetables	7.13	8.19	6.73	7.25
Processed cereal foods	35.87	31.06	31.58	32.43
All mandate cereals	3.02	2.96	2.99	2.99
All mandate legumes	24.20	24.11	24.22	24.18
All	5.33	5.47	5.50	5.43

Source: ICRISAT-FPRI, Alternative indicators village survey 1992/93.

Table 8. Kilograms consumed (kg capita^{-1} week^{-1}) by expenditure tercile and food group.

Food group	Expenditure tercile 1	2	3	All
Maharashtra villages				
Rice	0.08	0.13	0.16	0.12
Sorghum	1.51	1.80	1.80	1.70
Pearl millet	0.03	0	0.02	0.02
Finger millet	0	0	0	0
Groundnut	0.05	0.10	0.19	0.11
Pigeonpea	0.13	0.14	0.10	0.13
Chickpea	0.04	0.03	0.03	0.03
Wheat	0.61	0.33	0.40	0.45
Maize	0.03	0.08	0.14	0.08
Non-mandate legumes	0.09	0.06	0.04	0.06
Milk/milk products	0.20	0.38	0.50	0.36
Meat/fish/eggs	0.02	0.01	0.02	0.02
Other vegetables	0.27	0.26	0.32	0.28
Fruit	0.09	0.07	0.07	0.07
Sugar/spices	0.27	0.24	0.23	0.25
Other oilseeds	0.07	0.05	0.03	0.05
Green leafy vegetables	0.04	0.08	0.13	0.08
Processed cereal foods	0.05	0.04	0.03	0.04
All mandate cereals	1.54	1.80	1.82	1.72
All mandate legumes	0.22	0.27	0.32	0.27
All	22.52	24.99	27.91	25.14
Andhra Pradesh villages				
Rice	2.72	2.71	2.65	2.70
Sorghum	0.39	0.45	0.42	0.42
Pearl millet	0.02	0.09	0.08	0.06
Finger millet	0.01	0.03	0.01	0.16
Groundnut	0.05	0.05	0.07	0.06
Pigeonpea	0.05	0.05	0.05	0.05
Chickpea	0	0	0.01	0
Wheat	0	0.02	0.01	0.01
Maize	0	0	0	0
Non-mandate legumes	0.01	0.14	0.02	0.02
Milk/milk products	0.37	0.42	0.84	0.54
Meat/fish/eggs	0.03	0.04	0.03	0.03
Other vegetables	0.43	0.54	0.54	0.50
Fruit	0.01	0.05	0.03	0.03
Sugar/spices	0.10	0.10	0.13	0.11
Other oilseeds	0	0.01	0.01	0.01
Green leafy vegetables	0.03	0.02	0.03	0.02
Processed cereal foods	0.02	0.03	0.02	0.03
All mandate cereals	0.42	0.57	0.51	0.50
All mandate legumes	0.10	0.10	0.12	0.11
All	22.65	25.31	27.35	25.10

Source: ICRISAT -IFPRI, Alternative indicators village survey 1992/93.

VI. Dietary sources of energy: what role do the mandate crops play in satisfying energy needs?

Table 9 shows mean energy intakes (derived from the six 24-hour dietary recalls) by location of village, income group, and food group. Energy intake is disaggregated by food group to determine the contribution of each of the mandate crops to total energy intakes. Three patterns are evident. Firstly, Table 9 illustrates the extent to which rural populations are dependent on cereal crops. In the Maharashtrian villages, for example, cereals comprise roughly 70% of total calories, while in the Andhra villages they comprise over 85% of total calories. These results are consistent with a priori expectations of simple, monotonous diets in these poor areas.

Secondly, Table 9 also reveals a striking difference in mandate crop consumption in the two study areas. Households in the Maharashtrian villages derive 62% of energy consumed from ICRISAT's mandate crops, and 50% from sorghum alone. By contrast, the Andhra villages consume only 19% of energy from mandate crops. Rice is the preferred cereal and contributes over 70% of the total energy to the diet. Sorghum provides only 11% of the total dietary energy.

The Andhra preference for rice to sorghum is even more clear when the per kilogram (Table 7) and energy costs (Table 10) are compared. Table 7 shows that per kilogram sorghum is indeed cheaper than rice in the Andhra villages. Prices shown in Table 7 represent the average prices faced by households in each expenditure tertile. Some foods (e.g., sorghum in Maharashtra and rice in Andhra Pradesh) are offered by the state government at subsidized prices; hence, for these goods the average prices in Table 7 represent a mix of free market and subsidized prices. In Andhra Pradesh, a limited quantity of ration rice is available to most households at 3.5 rupees per kilogram (as opposed to roughly 4.8-5.6 rupees per kilo for market rice). The price of sorghum ranges from 2.8 to 3.8 Rs. kg^{-1} in the Andhra villages. Subsidized rice is rationed, however, and the monthly allocation is not enough to sustain a whole household. Nevertheless, it lowers the average price of energy from rice below the market price (even though rice remains slightly more expensive than sorghum). Despite these cost differentials, the Andhras clearly prefer rice as their primary source of energy. Table 10, however, shows the kilocalories of energy provided per rupee of food expenditure at each location. A comparison among the grains illustrates that sorghum and millets (specifically, pearl and finger millets) provide the cheapest source of energy at both locations. Sorghum, in fact, provides 60-80% more calories per rupee than rice. As an indication of the relative 'efficiency' of consuming sorghum over rice, consider that roughly 2.8 rupees per day will provide the recommended daily allowance (RDA) for energy from a sorghum-only diet in the Andhra villages. Table 10 shows that in the Andhra villages 1 rupee buys 1162 kcals of energy from sorghum. The RDA for the reference person is 2875 kcals. Thus, 5 rupees will buy the RDA of 2875 kcals, if only sorghum is consumed. By contrast, 1 rupee buys only 711 kcals of energy from rice. In the Maharashtra villages 1 rupee buys 1017 kcals of energy. Thus, it costs roughly 2.5 rupees to purchase the RDA from a strictly sorghum diet. By contrast, 5 rupees per day is needed to provide the RDA from rice. Note that this comparison is provided only to illustrate the relative cost of obtaining energy from various food sources. This comparison does not imply that it is desirable for households to consume a diet comprised of only one food (e.g., rice or sorghum).

Finally, Table 9 also shows that Maharashtrian diets are much more diversified than Andhran diets. Both groups consume a large amount of energy from cereals, but the Maharashtrians draw more calories from pulses and cooking ingredients (sugar,

Table 9. Household energy intake (kcals adult equivalent^{-1} day^{-1}) by expenditure tercile and food group.

	Expenditure tercile			
Food group	1	2	3	All
Maharashtra villages				
Rice	52	83	92	75
Sorghum	946	1 092	1 047	1 028
Pearl millet	18	0	13	16
Finger millet	0	0	0	0
Groundnut	75	120	225	140
Pigeonpea	70	74	58	67
Chickpea	26	21	18	22
Wheat	376	196	205	266
Maize	16	49	75	47
Non-mandate legumes	57	36	21	38
Milk/milk products	30	55	74	53
Meat/ fish/eggs	6	5	5	5
Other vegetables	21	20	19	20
Fruit	12	9	7	09
Sugar/spices	191	161	146	166
Other oilseeds	100	70	36	69
Green leafy vegetables	3	5	8	5
Processed cereal foods	16	13	11	13
All mandate cereals	964	1 092	1 060	1 039
All mandate legumes	171	215	301	229
All	2 013	2 008	2 081	2 040
Andhra Pradesh villages				
Rice	1 773	1 713	1 602	1 696
Sorghum	260	289	259	269
Pearl millet	17	55	50	41
Finger millet	6	17	5	9
Groundnut	78	88	113	93
Pigeonpea	30	32	32	31
Chickpea	3	4	6	5
Wheat	3	16	8	9
Maize	0	0	0	0
Non-mandate legumes	8	9	13	10
Milk/milk products	60	62	100	74
Meat/fish/eggs	9	11	10	10
Other vegetables	25	26	27	26
Fruit	2	9	3	5
Sugar/spices	57	58	73	63
Other oilseeds	6	27	6	7
Green leafy vegetables	2	1	1	1
Processed cereal foods	8	8	8	8
AH mandate cereals	283	361	314	319
All mandate legumes	111	124	151	129
All	2 344	2 408	2 315	2 355

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

Table 10. Energy (kcals) purchased rupee^{-1} by expenditure tercile and food group.

	Expenditure tercile			
Food group	1	2	3	All
Maharashtra villages				
Rice	539	576	574	566
Sorghum	1 322	1 005	754	1 017
Pearl millet	871	0	954	914
Finger millet	0	0	0	0
Groundnut	268	321	305	303
Pigeonpea	212	211	187	204
Chickpea	345	330	293	327
Wheat	445	455	469	454
Maize	880	848	834	843
Non-mandate legumes	396	323	229	344
Milk/milk products	108	136	139	132
Meat/fish/eggs	97	60	74	78
Other vegetables	187	176	150	172
Fruit	164	165	171	166
Sugar/spices	470	470	433	459
Other oilseeds	308	264	376	305
Green leafy vegetables	156	148	165	158
Processed cereal foods	148	125	203	156
All mandate cereals	1 312	1 005	758	1 015
All mandate legumes	257	285	280	276
All	833	722	591	714
Andhra Pradesh villages				
Rice	749	708	695	720
Sorghum	1 177	1 161	1 168	1 169
Pearl millet	1 209	1 284	1 246	1 258
Finger millet	1 247	1 243	1 234	1 243
Groundnut	279	283	292	285
Pigeonpea	194	191	189	192
Chickpea	310	300	317	310
Wheat	538	511	493	509
Maize	0	0	0	0
Non-mandate legumes	274	456	527	438
Milk/milk products	242	261	173	220
Meat/fish/eggs	83	78	76	79
Other vegetables	149	132	140	140
Fruit	137	171	227	183
Sugar/spices	423	427	461	437
Other oilseeds	225	312	265	271
Green leafy vegetables	81	53	60	66
Processed cereal foods	108	99	125	110
All mandate cereals	1 181	1 181	1 186	1 182
All mandate legumes	251	257	269	261
All	741	723	689	720

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

groundnut oil, and spices) than the Andhras. In the Maharashtra villages 14% of total dietary energy is provided by legumes, 11% by mandate legumes; in Andhra Pradesh almost all of the 6% of energy provided by legumes is provided by mandate legumes. In both areas the majority of these calories are provided from groundnut (usually in the form of edible oil).

Recent evidence from NIN validates that these three patterns are representative of current consumption patterns in each state (NNMB 1993). The NNMB surveys of 1990/91, for example, show that Andhra diets drew roughly 450 more calories from cereals than did Maharashtrian diets. The NNMB reports that the average intake of cereals was 523 grams in Andhra Pradesh and 390 grams in Maharashtra. Assuming an average caloric density of 3.5 kcal g^{-1}, this leads to a difference of 465 kcal between the two areas that is attributable to cereals alone. In addition, the NNMB data also show sorghum emerging as the principal source of dietary energy in Maharashtra and rice as the dominant source in Andhra Pradesh. Intake information on other food groups supports the notion that diets are generally much more diverse in Maharashtra. The NNMB data confirm that pulses, oil, and sugar consumption in the Ten-State Study are substantially higher in Maharashtra than in Andhra.

Evidence drawn from ICRISAT's prior study of these villages also indicates that these dietary patterns are part of a longstanding set of regional dietary preferences. An analysis of the dietary data collected from the same villages in 1977/78 illustrates that households have long been dependent on cereal crops to meet the majority of their energy needs (Table 11). In Andhra Pradesh villages in 1977/78 over 90% of all energy consumed was derived from cereals. In contrast to the Andhras, the Maharashtrian diet was much more diversified and contained greater quantities of pulses, groundnut, wheat, and milk products. Even so, 59% of all energy consumed was still derived from cereals.

Table 11 also shows the same striking difference in mandate crop consumption between the two study areas. In Maharashtra, over 62% of total energy was derived from the mandate crops in 1977/78, with 43% from sorghum alone. By contrast, in Andhra Pradesh, only 19% of total energy was consumed from the mandate crops. Rice, by far, contributed the largest amount of energy, amounting to over 73% of total energy.

These data illustrate that diets in these areas have changed very little over the past 15 years. Grains continue to be the dominant source of energy, with the Andhrans eating mostly rice and the Maharashtrians eating mostly sorghum. The Maharashtrian diet, however, has proven to be more diverse, including larger quantities of legumes, dairy products, and wheat.

VII. Iron and vitamin A: assessing the role of mandate crops in providing dietary diversity

The previous section illustrates that staple food preferences are distinct in the two study areas, and that they resemble patterns observed in the late 1970s. Energy continues to be provided primarily by two cereals, sorghum and rice, each showing greater importance in differing regions. But what about micronutrient intakes? The analysis of the 1977/78 dietary data showed that diets were highly deficient in carotene, vitamin C, iron, and riboflavin and that these deficiencies persisted 15 years later. This section therefore examines current levels of intake for two key micronutrients, iron and vitamin A, together with the primary food sources for each.

Iron

Table 12 shows the principal sources of dietary iron at each location. Total iron intakes are low at both locations. In addition, disaggregating

Table 11. A comparison of household energy intakes (kcals adult equivalent^{-1} day^{-1}) in 1977/78 and 1992/93, by location and food group.

	Andhra Pradesh		Maharashra	
Food group	1977/78[1]	1992/93[2]	1977/78[1]	1992/93[2]
Rice	1 625	1 696	14	75
Sorghum	211	269	816	1 028
Pearl millet	119	41	0	16
Finger millet	36	9	0	0
Groundnut	51	93	192	140
Pigeonpea	37	31	92	67
Chickpea	10	5	66	22
Wheat	8	9	188	266
Maize	0	0	101	47
Non-mandate legumes	8	10	41	38
Milk/milk products	32	74	61	53
Meat/fish/eggs	24	10	2	5
Other vegetables	20	26	16	20
Fruit	0	5	6	9
Sugar/spices	18	63	280	166
Other oilseeds	10	7	8	69
Green leafy vegetables	1	1	1	5
Processed cereal foods	1	8	1	13
All mandate cereals	366	319	816	1 039
All mandate legumes	98	129	350	229
All	2 217	2 355	1 884	2 040

1. Source: ICRISAT VLS dietary survey 1977/78.
2. Source: ICRISAT-IFPRI Alternative indicators village survey 1992/93.

total intakes by sources of iron indicates that low intakes are due to a lack of diverse and rich sources of dietary iron. Cereals, for example, are the main source of dietary iron in both areas. In the Maharashtra villages cereals provide over 80% of total dietary iron, while in the Andhra villages cereals provide over 70% of total iron. The limited set of dietary sources is even more clear when the top iron food sources are identified for each area. Iron sources are notably concentrated in only a couple of foods: sorghum and wheat in Maharashtra, and rice and sorghum in Andhra Pradesh. In Maharashtra sorghum alone contributes approximately 60% of total dietary iron; in Andhra Pradesh rice (32%) and sorghum (30%) provide roughly equal shares to the diet. The preference for rice to sorghum in the Andhra villages has significant implications for dietary iron intake. Milled rice, for example, contains approximately one-quarter of the iron that sorghum does (Gopalan et al. 1994); as such, iron intake in the Andhra villages is approximately half that found in the Maharashtra villages.

In developed countries cereals are typically considered poor sources of dietary iron. In this study region, however, households consume such large quantities of cereals (and such small quantities of iron-rich foods) that cereals become the greatest contributor of iron. By contrast, foods that are known to be iron-rich (e.g., green leafy vegetables) provide insignificant quantities of dietary iron.

The lack of diverse iron sources also means that the iron-income relationship follows the

Table 12. Sources of dietary iron (mg adult equivalent^{-1} day^{-1}) by expenditure tercile and food group.

Food group	Expenditure tercile 1	2	3	All
Maharashtra villages				
Rice	0.09	0.15	0.16	0.13
Sorghum	9.52	11.20	10.61	10.45
Pearl millet	0.31	0	0.24	0.28
Finger millet	0	0	0	0
Groundnut	0.09	0.27	0.45	0.27
Pigeonpea	0.48	0.51	0.40	0.46
Chickpea	0.31	0.25	0.21	0.26
Wheat	4.48	2.34	2.74	3.18
Maize	0.10	0.30	0.45	0.28
Non-mandate legumes	0.63	0.59	0.42	0.55
Milk/milk products	0.07	0.13	0.16	0.12
Meat/fish/eggs	0.06	0.05	0.05	0.05
Other vegetables	0.26	0.27	0.33	0.29
Fruit	0.13	0.07	0.22	0.14
Sugar/spices	0.33	0.26	0.16	0.25
Other oilseeds	0.16	0.08	0.09	0.11
Green leafy vegetables	0.12	0.38	0.62	0.38
Processed cereal foods	0.12	0.08	0.20	0.13
All mandate cereals	9.83	11.47	10.85	10.72
All mandate legumes	0.88	1.03	1.06	0.99
All	17.27	16.95	17.51	17.33
Andhra Pradesh villages				
Rice	2.98	2.88	2.60	2.81
Sorghum	2.50	2.87	2.41	2.60
Pearl millet	0.33	1.09	0.91	0.78
Finger millet	0.06	0.17	0.04	0.09
Groundnut	0.01	0.02	0.03	0.02
Pigeonpea	0.19	0.20	0.20	0.20
Chickpea	0.03	0.05	0.08	0.06
Wheat	0.03	0.13	0.07	0.08
Maize	0	0	0	0
Non-mandate legumes	0.09	0.12	0.18	0.13
Milk/milk products	0.10	0.11	0.19	0.13
Meat/fish/eggs	0.08	0.11	0.09	0.09
Other vegetables	0.47	0.51	0.48	0.49
Fruit	0.02	0.03	0.04	0.03
Sugar/spices	0.88	0.83	0.76	0.82
Other oilseeds	0.06	0.08	0.07	0.07
Green leafy vegetables	0.15	0.05	0.08	0.09
Processed cereal foods	0.03	0.04	0.03	0.03
All mandate cereals	2.89	4.13	3.36	3.46
All mandate legumes	0.23	0.27	0.31	0.27
All	7.99	9.76	8.28	8.68

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

same pattern as the energy-income pattern. Table 12, for example, indicates that iron intakes are fairly constant across income groups. The invariance of iron intakes to changes in income is a direct consequence of the fact that meats (a very rich source of dietary iron) are not widely consumed for cultural reasons. The means shown in Table 12 indicate that meat consumption remains low at all income levels. By contrast, cereals are the main source of iron and their intakes do not rise dramatically with income level. Therefore, dietary iron does not rise with increases in income at either location.

The effect of relying so heavily on staple foods differs according to staple crop preferences. Because iron consumption is concentrated in cereals (and cereals provide the majority of total energy) some minimal amount of iron will always be consumed. However, the lack of diverse iron sources places the rice-consuming areas at a relative disadvantage in terms of iron nutrition. In Andhra Pradesh, households strongly prefer rice to sorghum. As such, households will always prefer to consume a grain that is relatively iron-poor. Furthermore, so long as rice is subsidized in Andhra Pradesh, households will continue to choose rice over sorghum, even though sorghum is a far richer source of iron.

This situation is in contrast to that in the Maharashtrian villages where diets are principally dependent on sorghum and to a lesser extent on wheat. In comparison to rice, both of these crops are relatively iron-rich and as a result, substituting one for another does not have an adverse effect on iron consumption. Hence, even as sorghum prices rise, households respond by increasing consumption of low-quality sorghum, increasing wheat purchases, or reducing purchases of non-staple foods. Iron consumption therefore remains relatively stable.

Table 13 illustrates the cost of dietary iron from various food sources. The figures are not adjusted for different levels of bioavailability between heme and non-heme iron sources. Adjusting the meat entries for the higher bioavailability of heme iron in meat products, however, would still not change the finding that coarse grains are the cheapest source of dietary iron. Under the assumptions that heme iron is 20-30% bioavailable and non-heme iron is 5% bioavailable, meat products are still an expensive source of bioavailable iron. In the Maharashtra villages green leafy vegetables (GLVs) provide a relatively cheap source of iron. By contrast, GLVs are fairly expensive sources of iron in the Andhra villages. The difference in the relative cost of dietary iron from GLVs between these areas is large and is due to: (1) the consumption of such highly iron-rich vegetables as shepu in Maharashtra, and (2) the relative availability of GLVs in the Maharashtra villages versus the Andhra villages. These differences also suggest significant possibilities for improving horticulture enterprises in the Andhra villages and thus making GLVs a more reasonably-priced source of dietary iron.

In terms of ICRISAT mandate crops, Table 13 illustrates that sorghum and millets are also cheap sources of iron. Millets, however, are an inferior staple food and are rarely consumed in these areas. Again, the Mahrastrans appear to be at an advantage in terms of acquiring reasonably-priced iron from their preferred cereals. In Maharashtra, for example, the iron RDA (28 mg) can be purchased for roughly 2.4 rupees per day from sorghum alone. Thus, households that are capable of meeting their energy needs from a sorghum-based diet (at a cost of about 2.5 rupees per day) will meet their iron requirements in the process. This situation, however, is in contrast to that faced by rice-consuming households. Table 13 indicates that rice ranks as one of the more expensive sources of iron. Yet, because so much rice is consumed in Andhra Pradesh, rice is still the principal source of iron in these villages. Table 6 demonstrates that low-income households in Andhra Pradesh spend approximately 3.5 rupees per capita per day on food. Table 13 shows that households in the lowest expenditure tercile obtain only 1.5 mg of iron per rupee

Table 13. Iron (mg) purchased rupee^{-1} by expenditure tercile and food group.

	Expenditure tercile			
Food group	1	2	3	All
Maharashtra villages				
Rice	1.10	1.17	1.17	1.15
Sorghum	15.53	11.81	8.85	11.94
Pearl millet	19.30	0	21.14	20.25
Finger millet	0	0	0	0
Groundnut	0	0	0	0
Pigeonpea	1.59	2.00	1.71	1.78
Chickpea	1.73	1.73	1.52	1.67
Wheat	4.91	4.92	4.17	4.72
Maize	6.38	6.52	6.72	6.51
Non-mandate legumes	5.87	6.77	5.35	5.67
Milk/milk products	0.31	0.42	0.44	0.41
Meat/fish/eggs	1.24	.82	1.01	1.04
Other vegetables	2.32	1.83	1.88	2.02
Fruit	1.68	1.70	4.31	2.32
Sugar/spices	3.19	3.19	2.88	3.09
Other oilseeds	3.47	2.32	3.17	3.08
Green leafy vegetables	12.35	32.04	35.07	31.77
Processed cereal foods	7.12	8.95	17.60	13.01
All mandate cereals	15.67	11.81	9.31	12.16
All mandate legumes	2.89	2.57	2.11	2.50
All	11.22	10.01	8.95	10.10
Andhra Pradesh villages				
Rice	1.52	1.44	1.41	1.46
Sorghum	13.83	13.64	13.73	13.73
Pearl millet	26.78	28.44	27.62	27.88
Finger millet	14.83	14.79	14.68	14.78
Groundnut	1.65	1.77	2.14	1.91
Pigeonpea	1.57	1.54	1.52	1.54
Chickpea	4.63	4.76	5.56	5.07
Wheat	7.38	6.73	6.71	6.80
Maize	0	0	0	0
Non-mandate legumes	5.68	11.04	12.65	10.51
Milk/milk products	0.42	0.44	0.31	0.37
Meat/fish/eggs	1.12	0.94	0.97	1.00
Other vegetables	3.13	2.89	3.09	3.03
Fruit	2.08	.80	1.14	1.23
Sugar/spices	13.23	13.29	12.29	13.01
Other oilseeds	3.80	5.00	4.45	4.47
Green leafy vegetables	4.45	3.01	2.51	3.49
Processed cereal foods	2.14	1.79	1.53	1.83
All mandate cereals	15.12	17.25	18.22	16.91
All mandate legumes	2.00	2.05	2.60	2.23
All	7.98	9.87	9.91	9.25

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

1. At the time of the study, 1 rupee (=100 paise) = 0.03 USD.

spent on rice. Thus, it is virtually impossible for the lowest income group to obtain the iron RDA on their predominantly rice-based diets. Clearly efforts to increase the availability of reasonably-priced iron-rich GLVs in these areas are much needed.

Carotene

Table 14 disaggregates carotene sources by food group. Perhaps the most striking result from this table is that carotene intakes are so low. In the Andhra villages average intakes of carotene total about one-fifth of requirements; in the Maharashtra villages average intakes approach two-fifths of requirements. Beyond this, however, it is noted that in Andhra Pradesh carotene is mostly derived from vegetables (leafy and otherwise), while in Maharashtra carotene is mostly derived from GLVs. Leafy vegetable consumption is also much greater in the Maharashtrian villages than in the Andhra villages. Disaggregating Table 14 by village reveals substantial village-level differences in carotene food sources between the two Maharashtrian villages. Specifically, Table 15 shows that GLVs are far more important sources of carotene in Shirapur than in any other village. In fact, in Kanzara, carotene consumption from GLVs more closely follows the pattern displayed in the Andhra villages. Kanzara, however, is uniquely distinguished from the other villages in that fruit consumption contributes significantly to total carotene intakes. The Andhra villages, by contrast, show patterns of consumption that are consistent with each other: low levels of carotene intake, with only modest increases between the lowest and highest income levels coming from milk and leafy vegetables. These findings are broadly consistent with those reported in Ryan et al. (1984) and suggest again that dietary patterns have not changed drastically during the intervening 15 years.

Table 16 shows the carotene cost by food group, expenditure tercile, and location. In the Maharashtrian villages GLVs are exceptionally cheap sources of carotene; less than 15 paise (approximately 0.005 USD) is needed to provide the recommended daily allowance for the reference person (2400 mg). In the Andhra villages GLVs are twice as expensive, but are still fairly cheap sources of carotene. Less than 30 paise are needed to buy the recommended daily allowance. Clearly cost is not the reason for low intakes in these areas.

VIII. Seasonality of nutrient consumption

In this section, nutrient intakes are disaggregated by round to explore the seasonal fluctuations in energy, iron, and carotene. Because of the interactive effect between iron bioavailability and vitamin C intake, seasonal fluctuations in vitamin C are also presented.

Table 17 shows the percentage of households consuming less than 70% of requirements by survey round and by location. The first round represents the rainy, cropping season; the second represents the postrainy cropping season; and the third round represents the hot, dry summer season. Table 17 illustrates that fluctuations in nutrient intakes are greater in the Maharashtrian villages than in the Andhra villages. In Andhra Pradesh, energy, iron, carotene, and vitamin C intakes are relatively stable over time, although iron, carotene, and vitamin C levels are persistently low. Diets, however, appear to be energy-adequate throughout the year, most likely due to the state-wide program that provides rationed quantities of subsidized rice. Because of this preference for rice together with the low levels of GLV consumption, the percentage of households consuming inadequate iron intake levels remains high throughout the year. Finally, there is some seasonal variation in vitamin C intakes, but the percentage of households with low intakes is still high in every season.

The Maharashtrian villages display far more seasonality in nutrient intakes. Energy intakes, for example, are much less stable over

Table 14. Source of dietary carotene (mg adult equivalent^{-1} day^{-1}), by expenditure tercile and food group.

Food group	Expenditure tercile 1	2	3	All
Maharashtra villages				
Rice	0	0	0	0
Sorghum	106.5	127.0	124.0	119.0
Pearl millet	5.0	0.2	4.0	4.8
Finger millet	0	0	0	0
Groundnut	0.1	0	0	0.1
Pigeonpea	34.0	39.0	22.0	31.7
Chickpea	7.0	6.0	5.0	6.0
Wheat	25.8	14.0	17.0	19.0
Maize	4.0	10.0	18.0	11.0
Non-mandate legumes	6.0	3.0	1.0	3.4
Milk/milk products	60.0	114.0	151.0	109.0
Meat/fish/eggs	4.0	5.0	6.0	5.0
Other vegetables	39.0	47.0	53.0	46.0
Fruit	226.0	123.0	36.0	128.0
Sugar/spices	0.4	2.0	1.0	1.0
Other oilseeds	4.1	1.0	1.0	2.1
Green leafy vegetables	268.0	528.0	881.0	559.0
Processed cereal foods	0.7	0.5	0.3	0.5
All mandate cereals	111.5	127.2	128.0	122.2
All mandate legumes	41.1	45.0	27.0	37.0
All	791.0	1 021.0	1 322.0	1 046.0
Andhra Pradesh villages				
Rice	0	0	0	0
Sorghum	28.0	32.0	29.0	29.0
Pearl millet	0.5	17.0	15.0	13.0
Finger millet	0.6	2.0	0	1.0
Groundnut	0.1	0.1	0	0.1
Pigeonpea	9.3	9.9	10.0	9.8
Chickpea	0.7	1.2	2.0	1.2
Wheat	0.1	0.7	0.0	0.4
Maize	0	0	0	0
Non-mandate legumes	1.0	1.0	1.6	1.2
Milk/milk products	78.0	83.0	131.0	97.0
Meat/fish/eggs	39.0	28.0	41.0	36.0
Other vegetables	101.0	118.0	111.0	110.0
Fruit	25.0	8.0	5.0	13.0
Sugar/spices	8.0	7.0	9.0	8.0
Other oilseeds	0.3	0.3	0.4	0.3
Green leafy vegetables	167.0	121.0	184.0	157.0
Processed cereal foods	0.2	0.2	0.2	0.2
All mandate cereals	29.2	51.0	44.0	41.36
All mandate legumes	10.1	11.2	12.0	11.10
All	463.0	427.0	541.0	477.0

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

Table 15a. Food sources of carotene (mg) by expenditure tercile and food group, Maharashtra villages.

	Expenditure tercile			
Food group	1	2	3	All
Shirapur village				
Rice	0	0	0	0
Sorghum	139	140	129	136
Millets	0	4	0	4
Other cereals	29	39	27	31
Pulses	11	17	20	16
Milk	104	146	163	138
Other vegetables	51	53	63	56
Fruit	2	16	7	9
Cooking ingredients	3	3	3	3
Meat	1	7	4	4
Green leafy vegetables	847	567	1 186	867
All vegetables	898	620	1 249	922
Total	1 186	990	1 601	1 261
Kanzara village				
Rice	0	0	0	0
Sorghum	107	98	101	102
Millets	8	3	5	5
Other cereals	24	33	30	29
Pulses	56	55	91	67
Milk	52	68	110	77
Other vegetables	32	35	46	38
Fruit	279	206	263	249
Cooking ingredients	5	6	12	8
Meat	7	1	12	6
Green leafy vegetables	138	264	353	165
All vegetables	170	299	399	289
Total	708	767	1 023	745

Source: ICRISAT/IFPRI Alternative indicators village survey 1992/1993.

time. Undoubtedly, this is due to a number of reasons, but it is clear that the state's system of safety-nets has not been successful in stabilizing energy intakes. The Maharashtra state food subsidy scheme provides subsidized sorghum but consumers complain that the quality of sorghum is poor and that supplies are erratic. Similarly the Employment Guarantee Scheme (EGS) is not able to provide work for all that need it With the lack of effective safety-nets, the seasonality of energy intakes therefore follows the cycle of major harvests in the region. In Shirapur the main harvest is that of the postrainy season and the percentage of households falling below 70% of requirements is lowest then. In Kanzara the main harvest occurs in the rainy season and the percentage of households consuming low energy diets is lowest then. Because iron intakes are so closely tied to staple crop consumption, iron intakes follow the same pattern as energy intakes.

Carotene and vitamin C adequacies follow

Table 15b. Food sources of carotene by expenditure tercile and food group, Andhra Pradesh villages.

	Expenditure tercile			
Food group	1	2	3	All
Dokur village				
Rice	0	0	0	0
Sorghum	27	33	28	29
Millets	1	4	1	2
Other cereals	0	1	1	1
Pulses	14	15	21	17
Milk	108	96	146	117
Other vegetables	100	133	108	114
Fruit	48	1	21	23
Cooking ingredients	6	5	7	6
Meat	31	30	24	28
Green leafy vegetables	144	231	264	213
All vegetables	245	364	371	327
Total	477	549	619	548
Aurepalle village				
Rice	0	0	0	0
Sorghum	23	37	30	30
Millets	28	25	23	25
Other cereals	1	0	1	1
Pulses	5	5	14	8
Milk	38	44	153	78
Other vegetables	887	116	117	107
Fruit	2	3	1	2
Cooking ingredients	12	11	9	11
Meat	41	27	63	44
Green leafy vegetables	109	23	177	240
All vegetables	197	138	294	210
Total	347	291	588	546

Source: ICRISAT/IFPRI Alternative indicators village survey 1992/1993.

seasonal trends in Maharashtra, but even with seasonal "dips'' in consumption, the average Maharashtrian household is almost always better off than that in Andhra. Table 14 showed substantially higher intakes of carotene from vegetables and fruits in the Maharashtrian villages. Correspondingly Table 17 illustrates that carotene and vitamin C adequacies follow the seasonal availability of the major food sources within each village. Leafy vegetables, for example, are the major source of carotene and vitamin C in Shirapur and adequacy levels are correspondingly highest during the postrainy season. Similarly, in Kanzara carotene adequacy levels improve during the postrainy season, but improve even further in the summer season when mangoes are available in the village. Vitamin C adequacy, however, improves in the postrainy season due to increased vegetable consumption and then drops again during the summer.

In short, the Andhra villages appear to suffer from more persistent levels of low micronutrient intakes. The Maharashtrian villages on the whole

Table 16a. Carotene (mg) purchased rupee^{-1} by expenditure tercile and food group, Maharashtra villages.

	Expenditure tercile			
Food group	1	2	3	All
Rice	0	0	0	0
Sorghum	178	135	101	137
Pearl millet	318	0	349	334
Finger millet	0	0	0	0
Groundnut	17	22	0	19
Pigeonpea	435	442	179	373
Chickpea	119	114	101	113
Wheat	38	39	40	39
Maize	232	223	220	222
Non-mandate legumes	74	76	29	70
Milk/milk products	270	338	342	326
Meat/fish/eggs	1 030	1 285	1 012	1 122
Other vegetables	1 514	2 115	710	1 427
Fruit	3 557	3 595	3 389	3 549
Sugar/spices	240	233	294	256
Other oilseeds	600	559	487	576
Green leafy vegetables	20 712	19 170	22 084	20 953
Processed cereal foods	11	9	8	10
All mandate cereals	186	135	115	144
All mandate legumes	373	395	161	327
All	8 097	10 343	14 601	11 480

Source: ICRISAT-IFFRI, Alternative indicators village survey 1992/93.

consume diets poorer in energy intake, but richer in iron, carotene, and vitamin C. Although the Maharashtrians have higher micronutrient intakes, they experience seasonal swings in intakes of almost all the nutrients of interest. The Andhrans, by contrast, eat a diet with higher energy intake, but very poor in micronutrients. Thus, the intakes of all micronutrients of interest are low in any season and any location.

IX. Dietary protein: quantity but not quality?

Legumes are generally considered a good source of dietary protein. It is therefore appropriate to discuss the role that ICRISAT mandate crops play in providing dietary protein. Table 4 indicates that people living at both locations are consuming fairly sufficient quantities of protein. Table 18 disaggregates the protein intakes by source for each location. The pattern for protein consumption is very similar to that shown for energy; the vast majority of protein is derived from cereals. In Andhra Pradesh most protein is obtained from rice and in Maharashtra most is from sorghum. A very low percentage of protein is derived from legumes in all villages.

Protein adequacy, however, is assessed by the quality of the protein consumed in addition to the quantity consumed. Pulses, for example, are rich in amino acids (such as lysine) that are not present in most cereals. For this reason, NIN suggests that the proportion of cereal to

Table 16b. Carotene (mg) purchased rupee^{-1} by expenditure tercIle and food group, Andhra Pradesh villages.

	Expenditure tercile			
Food group	1	2	3	All
Rice	0	0	0	0
Sorghum	159	156	157	157
Pearl millet	442	469	456	460
Finger millet	160	160	158	159
Groundnut	23	25	24	24
Pigeonpea	77	75	74	76
Chickpea	107	103	106	106
Wheat	48	58	41	51
Maize	0	0	0	0
Non-mandate legumes	36	98	127	96
Milk/milk products	414	452	320	390
Meat/fish/eggs	1 262	1 172	1 209	1 220
Other vegetables	804	1 028	942	928
Fruit	4 735	3 103	4 782	4 422
Sugar/spices	227	205	231	222
Other oilseeds	29	35	35	33
Green leafy vegetables	9 950	7 297	9 099	8 812
Processed cereal foods	7	6	8	7
AH mandate cereals	197	255	279	246
All mandate legumes	79	77	78	78
All	3 819	2 723	3 264	3 277

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

pulse should not exceed 6:1 to ensure a proper balance of protein quality (Gopalan et al. 1994). In the Maharashtrian villages, the cereal to pulse consumption was roughly in a 8:1 ratio, higher than the recommended levels. Two mandate legumes, chickpea and pigeonpea, comprise the majority of pulse consumption. These legumes, despite their relatively meager contribution to overall energy intakes, do play a valuable role in providing an essential amino acid to the diet In the Andhra Pradesh villages, chickpea, pigeonpea, and all other legumes are eaten relatively sparingly in comparison to the Maharashtra villages. As a result, the cereal to pulse ratio is roughly 25:1, far below the ratio suggested by NIN. This finding would imply that Andhrans are most likely deficient in lysine, the essential amino acid found in pulses.

The patterns shown in the 1992/93 study are somewhat similar to those found by Ryan et al. (1984) 15 years earlier. More specifically, in 1977/78 the Maharashtra villages consumed a higher proportion of pulses than the Andhra villages. In 1977/78 the cereal:pulse ratio was 11:1 in Akola district and 16:1 in Sholapur district. In the Andhra villages it was only 35:1 in Aurepalle and 25:1 in Dokur. Pulse to cereal consumption ratios have certainly improved during the intervening years, but it is clear that the pattern between regions is still very similar. Research activities that increase the availability of pulses to consumers in both areas are therefore warranted.

Table 17. Percentage of households consuming <70% of requirements by village, round, and season.

	Andhra Pradesh		Maharashtra	
	Dokur	Aurepalle	Shirapur	Kanzara
Energy				
Rainy	32	31	63	36
Postrainy	21	36	44	56
Summer/early rainy	35	35	57	66
Iron				
Rainy	99	86	79	53
Postrainy	99	99	62	76
Summer/early rainy	99	99	78	76
Carotene				
Rainy	93	98	76	98
Postrainy	94	96	66	86
Summer/early rainy	98	95	84	73
Vitamin C				
Rainy	81	63	78	91
Postrainy	82	83	60	68
Summer/early rainy	93	86	83	96

Source: ICRISAT-IFPRt, Alternative indicators village survey 1992/93.

X. Conclusions

The objective of this study was to investigate consumption patterns for two areas of the Indian SAT and to discuss the implications for technology development. Particular emphasis was therefore placed on the consumption of key nutrients and their relationship to ICRISAT mandate crop consumption. The nutrient adequacies of energy iron, and carotene were examined in greater detail as these nutrients are of great public health significance in India (ACC/SCN 1992). Protein is also briefly discussed since the mandate legumes are potential sources of essential amino acids.

One of the most striking findings from this study is the level of undernutrition that exists in the study areas. Dietary patterns are very different in the two regions studied. Both areas, however, display deficiencies in almost all of ten essential nutrients, most notably energy, iron, and carotene. Energy intakes are certainly low, but even greater deficiencies are apparent in two key micronutrients: iron and carotene. This pattern of deficiencies is supported solidly by research conducted in the same villages 15 years earlier (Ryan et al. 1984). Although adequacy levels have risen significantly, they remain very low. It is remarkable how little progress there has been in improving nutritional intakes during the intervening years.

The low levels of iron and carotene intake are no doubt due to the fact that diets continue to be monotonous and heavily dependent on cereals. In both areas cereals provide over 60% of all calories consumed. In fact, most dietary energy is derived from a single staple food; in the Maharashtra villages the staple food is sorghum, in the Andhra villages it is rice. Furthermore, diets are practically devoid of any iron-rich meats. Green leafy vegetables are infrequently eaten in most of the study villages.

Table 18. Sources of dietary protein (g protein adult equivalent^{-1} day^{-1}) by expenditure tercile and food group.

	Expenditure tercile			
Food group	1	2	3	All
Maharashtra villages				
Rice	0.95	1.61	1.72	1.42
Sorghum	27.20	32.12	29.93	29.75
Pearl millet	0.51	0	0.39	0.45
Finger millet	0	0	0	0
Groundnut	0.86	2.61	4.31	2.59
Pigeonpea	4.59	4.84	3.65	4.36
Chickpea	1.36	1.09	0.92	1.12
Wheat	12.50	6.62	7.55	8.89
Maize	0.55	1.57	2.39	1.50
Non-mandate legumes	3.72	2.51	1.43	2.56
Milk/milk products	1.22	2.29	2.89	2.14
Meat/fish/eggs	0.52	0.49	0.46	0.49
Other vegetables	0.78	0.71	0.85	0.78
Fruit	0.11	0.09	0.08	0.10
Sugar/spices	0.09	0.11	0.07	0.09
Other oilseeds	0.25	0.10	0.13	0.16
Green leafy vegtables	0.20	0.40	0.64	0.41
Processed cereal foods	0.37	0.28	0.21	0.29
All mandate cereals	27.71	32.13	30.32	29.89
All mandate legumes	6.81	8.54	8.88	8.08
All	55.79	57.47	57.61	57.13
Andhra Pradesh villages				
Rice	32.79	31.38	28.83	31.00
Sorghum	7.13	8.12	6.92	7.39
Pearl millet	0.54	1.73	1.48	1.25
Finger millet	0.13	0.33	0.09	0.18
Groundnut	0.13	0.16	0.28	0.19
Pigeonpea	1.81	1.94	1.90	1.88
Chickpea	0.14	0.24	0.31	0.23
Wheat	0.11	0.51	0.23	0.28
Maize	0	0	0	0
Non-mandate legumes	0.52	0.60	0.83	0.65
Milk/milk products	2.12	2.19	3.65	2.65
Meat/fish/eggs	0.92	1.23	0.92	1.03
Other vegetables	1.28	1.04	0.93	1.03
Fruit	0.02	0.08	0.05	0.05
Sugar/spices	0.26	0.23	0.26	0.25
Other oilseeds	0.11	0.14	0.15	0.13
Green leafy vegetables	0.10	0.60	0.08	0.08
Processed cereal foods	0.11	0.13	0.12	0.12
All mandate cereals	7.80	10.18	8.49	8.82
All mandate legumes	2.08	2.34	2.49	5.24
All	48.08	50.11	47.04	48.40

Source: ICRISAT-IFPRI, Alternative indicators village survey 1992/93.

The ICRISAT mandate crops play a variable role in determining the nutrient mix of diets in the study villages. In the Maharashtra villages, for example, sorghum provides over 50% of all calories and iron consumed. Sorghum also provides the majority of protein to the diet. Protein adequacy, however, is assessed by both the quantity and the quality of the protein consumed. Cereals may provide the bulk of protein consumed, but pulses are rich in lysine, an essential amino acid that is lacking in most cereals. Since cereals and pulses are relatively low-cost sources of protein, India's NIN has provided a recommended ratio of cereal to pulse consumption of not less than 6:1 to ensure a proper balance of protein quality (Gopalan et al. 1994). In the Maharashtrian villages cereals and pulses are consumed in a ratio of 8:1. Two mandate legumes, chickpea and pigeonpea, comprise the majority of the pulse consumption. These two legumes therefore play a valuable role in providing an essential amino acid, although they contribute relatively little energy to the total diet.

Sorghum is also a significant source of carotene in the Maharashtrian villages. Although it is not typically considered a rich source of vitamin A, sorghum has become a major food source of carotene in this area since it is eaten so frequently and in such large quantities. Note, however, that this finding is more a testament to the very carotene-deficient diets in this area rather than proof of sorghum as an excellent (or recommended) source of carotene. The essential lesson to extract from this is that households do depend on sorghum for dietary carotene, but only because consumption of truly carotene-rich foods (such as leafy vegetables and animal products) is so low.

In contrast to the Maharashtrian villages, the Andhra diet is much less dependent on any of the mandate crops. Undoubtedly this is because rice is the chief staple in this area. But the mandate crops do make a valuable contribution to the diet in terms of iron consumption. Sorghum, finger millet, and pearl millet together provide over 40% of total dietary iron, although their consumption represents only 13% of all calories. By contrast, rice provides only 30% of dietary iron although it provides over 70% of total calories. The reasons for the high contribution from mandate cereals are twofold. Firstly, sorghum contains four times more iron than rice; pearl millet and finger millet provide approximately five times more. Secondly, the Andhra diet is also devoid of iron-rich meats and leafy vegetables. As a result, the coarse grains become a major contributor of dietary iron. The significance of these mandate cereals to dietary iron, however, should not be misinterpreted. The Andhran diet is relatively devoid of iron-rich foods and it is not reasonable for Andhrans to meet their iron requirements by increasing the consumption levels of any of the mandate crops. The bioavailability of iron from these foods is extremely low and consumption of iron from more iron-rich foods should be encouraged. In terms of the mandate legumes, chickpea and pigeonpea are eaten relatively sparingly. As a result, the cereal:pulse ratio is roughly 25:1, far below the ratio suggested by NIN.

The dietary patterns displayed in the study indicate that the mandate crops do play an important role in the diets of the rural poor. In addition, diets are currently inadequate with respect to several nutrients, specifically energy, iron, and vitamin A. What then is the role of technical change in improving these diets? The changes in nutrient intakes that occur with rising incomes provide some clues to guide ICRISAT's search for "nutrition-friendly" research strategies. Note, for example, that energy and iron intakes are not responsive to increases in income. In addition, within each location, the mix of cereals consumed does not vary much across income groups. Rather, households tend to consume the same mix of cereals, neither increasing nor decreasing the energy intake from any single cereal. Increases in income lead instead to purchases of more expensive grades of staples. These two pieces of information, taken together, suggest that per capita consumption of these staple foods

should not be expected to rise with incomes.

With respect to the continuing research on mandate crops, this finding yields one very clear point: grain quality is important even to poor consumers. The expenditure pattern in the Maharashtra villages clearly indicates that wealthier households choose to purchase more expensive grades of sorghum, pigeonpea, and chickpea, rather than purchasing more at the same price. Thus, it appears that consumers have a keen understanding of the characteristics they want in staple foods, and are willing to pay for them. Qualitative interviews with villagers in Aurepalle and Shirapur revealed an acute awareness of quality differences in the available cereals. This finding underscores the need for scientists to be keenly aware of preferred varietal attributes. It also suggests that scientists should focus as much on identifying and producing these attributes as on increasing yields.

Aside from the issue of grain quality, the seasonality of energy consumption in the Maharashtra villages implies that technology development can play a role in determining energy and iron adequacy. More specifically, iron and energy intakes are shown to fluctuate with the sorghum harvest. As such, intakes are likely to be more stable if yields could be: (1) stabilized across years, and (2) increased during the main sorghum season (thus providing more storage sorghum for "off-seasons"). The significant contribution of sorghum to iron intakes in the Andhra villages also indicates that yield stability may also improve dietary iron intakes. Hence, with respect to improving energy and iron intakes, it appears that the strategy of yield enhancement and stabilization is a nutrition-friendly goal for sorghum research. In areas where sorghum is not the dominant cereal crop (for example western Rajasthan), similar studies might be completed to determine the relative importance of the same research on pearl millet or finger millet. Note, however, that these efforts will merely stabilize current levels of iron intakes. Significant improvements in iron intakes will require greater consumption of iron-rich foods and complementary efforts in fortification, supplementation, and nutrition education. Closing the iron gap will therefore be highly dependent on efforts outside of agriculture.

The income-energy and income-carotene relationships also contain valuable information about the potential for mandate crop research to have an impact on carotene intakes in the Indian SAT. Sorghum and pigeonpea are significant contributors to total carotene intake in both areas. As suggested before, this finding is somewhat surprising given the relatively low levels of carotene present in each. Nevertheless, the high consumption of sorghum in Maharashtra makes it a dominant source of carotene, equivalent in importance to GLVs. In Andhra Pradesh, the near absence of any carotene-rich foods also makes sorghum and pigeonpea relatively important sources of carotene (despite their lower intakes relative to the Maharashtra villages). Although sorghum is a prime source of carotene in the study areas there is little potential for increasing carotene intakes through increased sorghum consumption. Since energy intakes are not responsive to increases in income it is unreasonable to believe that sorghum consumption (and hence carotene intakes) will rise with increased income.

Carotene, however, is more densely distributed in fruits and vegetables than in staple foods. In Maharashtra, carotene intakes from fruits and vegetables are responsive to changes in income and should therefore rise if income-generating schemes are successful in raising rural incomes, but the potential for increasing carotene intakes through such programs appears to be limited. For example, in Maharashtra a 170% increase in income (from the bottom tercile to the top) increases carotene to only 55% of the RDA. In the Andhran villages the story is much worse; carotene intakes do not appear to be responsive to increases in income. A 125% increase in income (from the bottom to the top income tercile) increases carotene intakes to only 22% of the RDA.

Clearly, efforts to improve carotene intakes will require more focused initiatives, many of which will require skills outside of ICRISAT's comparative advantage. The primary tools available for increasing carotene intakes include supplementation, fortification, and nutrition education. With vitamin A, however, fortification remains difficult. Sugar, rice, and some specialty foods (e.g., sweetened condensed milk and monosodium glutamate) have been fortified in other countries but have not been tried on a widespread scale in India. Similarly, supplementation through megadose capsules has not found widespread support within the nutrition community in India. Trowbridge et al (1993) report that the success of capsule supplementation programs has been uneven across the country. Reasons for poor coverage include inadequate supplies of vitmain A supplements, lack of coordination between health professionals, distribution of doses only through clinics, and lack of community awareness. Capsule supplementation is highly controversial in India. Although many scientists argue that vitamin A megadose capsules reduce both child mortality and vitamin A deficiency (Sommer and West 1996), other influential scientists such as Gopalan believe that more effort should be placed on raising consumption of locally available vitamin A-rich foods (Sudhir 1992). Advocates of food-based interventions maintain that they they are more sustainable than capsule programs as they do not require dependence on capsule doners. In addition, they more directly address the root problem of dietary deficiencies.

In the absence of viable supplementation or fortification efforts, nutrition education and horticulture programs become the focus for policy makers. Leafy vegetables are currently the cheapest source of carotene available in the study areas. However, due to both a lack of availability and a lack of awareness about carotene requirements, leafy vegetables are consumed infrequently. Efforts to increase carotene intakes through nutrition education services will depend heavily on efforts to increase home gardening.

The literature, however, is mixed regarding the success of this approach. A recent study in Indonesia indicated that beta-carotene-rich food supplements (such as sweet potato and dark green leafy vegetables or DGLVs) in combination with dietary fat supplements and deworming significantly improved vitamin A status among pre-school children (Jalal 1995). However, there is some question as to whether the source of carotene may have played a significant role in the absorption of beta-carotene. Another study from Indonesia suggested that increasing the consumption of DGLVs was not enough to show visible improvement in the serum vitamin A status among breastfeeding, anemic women (de Pee et al. 1995). Rather, increases were found in women who had received a beta-carotene enriched wafer instead of the DGLVs. Within SouthAsia, many organizations continue to experiment with horticulture programs, but the success of these programs is mixed (see for example, IVACG Secretariat 1998).

An interesting alternative involves a form of 'natural fortification.' In this scenario, scientists would breed a commonly consumed foodstuff, presumably a food grain, to contain higher quantities of micronutrients that are in short supply in the regular diet. This strategy does not fall in the traditional venue of 'yield enhancement' strategies as it clearly puts 'natural fortification' (though breeding) as the priority achievement for breeding research. Recent assessments by Graham and Welch (1996) suggest that this strategy holds great potential for improving micronutrient intakes among the poor. However, a gteat deal of controversy surrounds the probability for success of such a research venture. Opponents suggest that this strategy will require significantly long lead times to produce varieties that overcome the many production constraints in resource-poor areas such as the Indian SAT (Ito et al, personal communication 1995). Conditions may also vary among micro-climates, making it unlikely that a single variety would be successful in diverse areas. For this approach to be

successful, significant resources need to be invested in breeding research, with benefits expected only after 15-20 years. This alternative is therefore a long-term approach toward increasing micronutrient intakes, and is not expected show benefits in the near future. However, aside from engaging in horticulture research, this alternative is one of the most proactive ways in which ICRISAT could strengthen its commitment to research on agriculture-nutrition linkages. An ex-ante evaluation of these efforts would indicate if this research investment was warranted.

Without this formal evaluation, it appears that yield enhancement and yield stabilization strategies continue to be ICRISAT's most 'nutrition-friendly' approach toward breeding. Yield stabilization, for example, can help improve the seasonality of intakes that is experienced in areas where mandate crops are the primary source of energy or iron Yield enhancement can lower food costs to consumers, and improve the productivity and profits to farmers. This in turn leads to increased purchasing power for foods that are nutritionally more diverse.

We must also be realistic about the nutritional goals that can be achieved through technological development of the mandate crops. In the short-to-medium term, the links between agricultural research and micronutrient nutrition appear to be mediated through horticulture rather than through staple crop production As such, a yield stabilization or enhancement strategy for the mandate crops is unlikely to solve the existing micronutrient problem in the Indian SAT. Iron and carotene intakes are so low in these areas and their micronutrient densities too low in mandate crops to expect substantial increases from increased consumption. Furthermore, consumption behavior also suggests that per capita consumption will not rise with increasing incomes. Stabilizing yields of sorghum, however, may help to stabilize and protect the iron and carotene that is currently derived from current levels of consumption. This in itself will be a contribution toward improving household and individual nutritional status. However, solving the micronutrient problem will require a commitment to either a 'natural fortification' or horticulture strategy. In addition, addressing micronutrient deficiencies means relying on efforts that lie outside of ICRISAT's comparative advantage (e.g., supplementation, fortification, nutrition education, or horticulture) to improve micronutrient intakes. As such, collaborating with organizations that focus more directly on micronutrient-related issues may be ICRISAT's greatest strategy to improve food and micronutrient security in the Indian SAT.

In sum, ICRISAT must consider itself a partner in fighting undernutrition in the Indian SAT; but it should also recognize its limitations. Under its current mandate the Institute's primary contributions appear to be providing stable incomes and staple supplies to resource-poor farmers.

References

Administrative Committee on Coordination/ Subcommittee on Nutrition. 1992. Second report on the world nutrition situation. Volume I. Global and regional results. 80 pp.

Behrman, J.R. 1995. Household behavior and micronutrients. What we know and what we don't know. Working Papers on Agricultural Strategies for Micronutrients, no. 2. Washington DC, USA: The International Food Policy Research Institute. 47 pp. [Limited distribution.]

Bouis, H.E. 1996. A food demand system based on demand for characteristics: is there 'curvature' in the Slutsky Matrix, what do the curves look like and why? Journal of Development Economics 51(2):239-66.

Bouis, H.E., and Haddad, L.J. 1992. Are estimates of calorie-income elasticities too high? A recalibration of the plausible range, Journal of Development Economics 39(2):333-64,

Chung, K., Haddad L., Ramakrishna, J., and Riely, F. 1997. Identifying the food insecure: the application of mixed-method approaches in India. Washington DC, USA: The International Food policy Research Institute. 70 pp.

Chung, K. 1995. Data documentation for the ICRISAT-IFPRI alternative indicators study. Patancheru 502 324, Andhra Pradesh, India: Socioeconomics and Policy Division, International Crop Research Institute for the Semi-Arid Tropics. [Limited distribution.]

de Pee S., West, C.E., Muhilal Karyadi, D., and Hautvast, J. 1995. Lack of Improvement in vitamin A status with increased consumption of dark-green leafy vegetables. The Lancet 346: 75-81.

Graham, R.D., and Welch, R.M. 1996. Breeding for staple-food crops with micronutrient density. Working Papers on Agricultural Strategies for Micronutrients, no. 3. Washington DC, USA: The International Food Policy Research Institute. 79 pp. [Limited distribution.]

Gopalan, C., Sastri, B.,V. and Balasubramanian, S.C 1994. Nutritive value of foods. Hyderabad, India: National Institute of Nutrition. 156 pp.

Haddad, L., Chung, K., and Yasoda Devi, P. 1995. Alternative approaches to locating the food and nutrition insecure: work in progress in South India. Economic and Political Weekly 30(7-8): 392-402.

Hazell, P., and Ramasamy, C. 1991. The green revolution revisited. Baltimore, USA: The Johns Hopkins University Press. 286 pp.

Indian Council of Medical Research. 1994. Nutrient requirements and recommended dietary allowances for Indians. A report of the expert group of the Indian Council of Medical Research. Hyderabad, India: National Institute of Nutrition. 129 pp.

Ito, (X, Bidinger, R, Johansen, C.,and Seeling, B. 1995. Personal communication.

IVACG Secretariat. 1998. Sustainable control of vitamin A deficiency. Report of the XVIII International Vitamin A Consultative Group Meeting, Cairo, Egypt, 22-26 September 1997. Washington DC: ILSI Research Foundation. 139 pp.

Jalal, F. 1995. Effects of deworming, dietary fat intake and carotenoid-rich diets on vitamin A status of preschool children infected with *Ascaris lumbricoides* in West Sumatra Province, Indonesia. PhD thesis, Cornell University, Ithaca, New York, USA. 210 pp.

Kelley, T.G., Parthasarathy Rao, P, and Mandar, J. 1995. A proposed methodology for a study on changes in cropping patterns in the semi-arid tropics of India: the role of price and non-price factors. Socioeconomics and Policy Division Progress Report 118. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. [Limited distribution]

Mebrahtu, S., Pelletier, D., and Pinstrup-Anderson, P. 1995. Agriculture and nutrition. Pages 220-242 *in:* Child growth and nutrition in developing countries, (Pinstrtup Anderson P., Pelletier, D., and Alderman, H. eds). Ithaca, USA: Cornell University Press.

National Nutrition Monitoring Bureau. 1993. Report (1991-92). Hyderabad, India: National Institute of Nutrition, Indian Council of Medical Research.

Pinstrup-Anderson, P., Berg, A., and Forman, M 1984. International agricultural research and human nutrition. Washington DC, USA: International Food Policy Research Institute. 326 pp.

Pinstrup-Anderson, P. and Hazell, P. 1987. The impact of the green revolution and prospects for the future. Pages 106-118 *in:* Food policy: integrating supply, distribution and consumption (Gittinger, J., Leslie, J., and Hoisington, C., eds). Baltimore, USA: Johns Hopkins University Press.

Pinstrup-Anderson, P. and Jaramillo, M. 1991. The impact of technical change in rice production on food consumption and nutrition. Pages 85-104 *in:* The green revolution revisited (Hazell, P. and Ramasamy, C., eds.). Baltimore, USA: Johns Hopkins University Press.

Ryan, J.G., Sheldrake, R., Yadav, and Satya Pal. 1974. Human nutritional needs and crop breeding objectives in the semi-arid tropics. Occasional Paper 4. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 34 pp. [Limited distribution.]

Ryan, J.G., Bidinger, P.D., Prahlad Rao, N., and Pushpamma, P. 1984. The determinants of individual diets and nutritional status in six villages of Southern India. Research Bulletin no. 7. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 140 pp.

Sommer, A., and West, K. Jr. 1996. Vitamin A deficiency. New York: Oxford University Press. 438 pp.

Staatz, J.M and Bernsten, R.H. 1992. Technology development and food security Pages 21-46 *in* Proceedings of the Workshop on Social Science Research and the Collaborative Research Support Programs, 9-11 June, 1992, Lexington, Kentucky, USA. Washington DC, USA: United States Agency for International Development.

Sudhir, R. 1992. The politics of vitamin A. Health Action 5(6):9-11.

Trowbridge, F.L., Harris, S.S., Cook, J., Dunn, J.T., Florentino, R.F., Kodyat, B.A., Venkatesh Mannar, M.G., Reddy, V., Krasid Tontisirin, Underwood, B.A., and Yip, R. 1993. Coordinated strategies for controlling micronutrient malnutrition: a technical workshop. Journal of Nutrition 123: 775-787.

Walker, T.S., and Ryan, J.G. 1990. Village and household economies in India's semi-arid tropics. Baltimore, USA: Johns Hopkins University Press. 394 pp.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

Consultative Group on International Agricultural Research

ISBN 92-9066-390-1 Order code: IBE 052 16–98