VEGETABLES SUITABLE FOR ASSOCIATION WITH SUBSISTENCE MAIZE AND BEANS IN THE HIGHLANDS OF GUATEMALA*

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ABSTRACT

Associating vegetables with the maize and beans produced for subsistence would appear to offer good possibilities for increasing the income of smallholders of the Guatemalan highlands, (who often possess barely enough land to produce their subsistence requirements of maize and beans). In field experiments carried out in 1978, 1979 and 1980, broccoli, white potatoes, and carrots appeared to be the most promising vegetables for such associations since they were able to produce, respectively, more than 4000, 20,000, and 13,000 kg/ha of high quality produce, or some 40 to 60% of their pure stand yields, while maize yields showed no significant decrease from their pure stand levels and often surpassed 4000 kg/ha. Satisfactory bean yields were obtain by planting climbing beans in association with the maize or by planting bush beans in association with the maize prior to planting the vegetables. An analysis of vegetable yields under these conditions, showed that yields decreased more than costs of production. Thus, these systems would be a viable alternative to maize and bean production but not to pure stand vegetable production.

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However, few farmers in the Guatemalan highlands possess sufficient land, labor and capital to devote themselves to pure stand vegetable production nor might they be willing to forego maize and bean production on their own farms.

RESUMEN

El asociar hortalizas con maíz y frijol producidos para subsistencia pareciera ofrecer buenas posibilidades para aumentar el ingreso de los pequeños agricultores del altiplano de Guatemala, que frecuentemente poseen tierra suficiente para producir maíz y frijol para sus necesidades de subsistencia. Los experimentos de campo realizados en 1978, 1979 y 1980, indicaron que brocoli, papa y zanahoria son las hortalizas más promisorias para la asociación dado que podrían producir hasta 4000, 20000 y 13000 kg/ha respectivamente de brocoli, papas y zanahoria de alta calidad, o sea 40 y 60% de sus rendimientos en monocultivo, mientras que los rendimientos de maíz en asociación no difirieron significativamente de sus niveles en monocultivo y frecuentemente fueron superiores a 4000 kg/ha. Rendimientos satisfactorios de frijol podrían ser obtenidos al sembrar frijol enredador en asociación con el maíz o al sembrar frijol arbustivo en relevo con el maíz antes de sembrar las hortalizas.

Sin embargo, el análisis de los rendimientos bajo estas condiciones, mostró que los rendimientos disminuyeron más que los costos de producción cuando se asociaron las hortalizas con el maíz. Así, estos sistemas podrían ser una alternativa viable para la producción de maíz y frijol pero no para la producción de hortalizas. Sin embargo, pocos agricultores en el altiplano de Guatemala disponen de tierras, capital y mano de obra suficiente para dedicarse a la producción de hortalizas en monocultivos, además, no dejarían de producir maíz y frijol en sus propios terrenos.

INTRODUCTION AND REVIEW OF LITERATURE

With some 25,000 km^2, or nearly one quarter of the national area located at elevations above 1500 m (calculated from (17)), Guatemala is uniquely located to supply the rest of Central America with cool-season vegetables. Figure 1 shows that in 1979-1980, Guatemala export almost $10,000,000 worth of vegetables, some 60% of which were cool-season (8). Surprisingly, some 32% of these vegetables including almost all of the broccoli, cauliflower, snowpeas, and okra, went to the United States, a market which shows good sings of expanding (Figure 2). The traditional Central American customers for potatoes, cabbage, tomatoes, and onions were already in 1981 having considerable difficulties in obtaining sufficient foreign exchange for maintaining previous levels of imports. Thus, Guatemalan farmers were receiving as little as 40% 1980 prices for cabbage and potatoes.

As the broccoli, cauliflower, and snowpeas are frozen for export, traditional producing areas of cabbage and potatoes in the Western highlands, more than 100 km from Guatemala City could not convert to the new export crops, except for the 1% of the U.S. volume of these products exported to Mexico. The main centers (7) for this production were the departments of Guatemala, Sacatepequez, and Chimaltenango in the Central Highlands (Figure 3). The 1979 agricultural census (3) indicated that the same area had considerably increased its production of potatoes and cabbage since the 1964 census (2), and would now appear to be the leading production area of these crops as well.

While these three departments are relatively well-endowed with land for the production of these vegetables, having some 3171 km^2 of lands over 1500 m, some 2161 km^2 with deep soils, and 600 km^2 with slopes of less than 15% (about one third of the relatively flat land in the highlands) (15), the competition for such land is considerable. Firstly, and most obviously, there are some 1.5 million urban inhabitants of Guatemala City, mostly occupying that same flat land which would be so good for agriculture. In addition to these, there are some 44,000 farms of less than 20 has (2), a good size for intensive vegetable production, but they only have a total area of some 115,000 has, or about 2 1/2 hectares per farm. I should point out that the farms over 20 has occupy some 150,000 has but many of these are at lower elevations; and their owners find it more profitable to raise coffee, sugar, or cattle for export. Although, one should be able to produce a considerable amount of vegetables on 115,000 has, even if it is divided up in 44,000 farms, there are at least three complications:

1) These farmers are primarily concerned with producing maize and beans for subsistence. Once they have obtained their level of subsistence, they turn to producing things that can be sold off the farm (4). In fact, Gladwin (6) has concluded that they only take land out of maize if the alternative is twice as profitable as maize, not such an easy requirement.

2) The same closeness to urban markets and freezing plants that favors vegetable production also means that there is a market for excess labor in the cities, easily reached by bus. It has been stated that no fewer than 2000 people board the bus daily in the town of Sumpango, a major cabbage producing area, to go to jobs, in Guatemala City some 40 km away. Of our 44,000 small farmers, some might choose crops which leave them sufficient time to work elsewhere, which would certainly not be vegetables. Furthermore, the largest rural group in this area are not landholders at all (2, 3) and wages paid to rural labor are generally lower than those in Guatemala City.

3) Most vegetables require a much larger capital investment than maize and beans, generally larger than most farmers in the area have at their disposal. Thus the average potato producing farm in the department of Guatemala has only 0.6 has of potatoes; while the average cabbage producing farm has only 0.4 has of cabbage (3).

Some of the farmers in the area follow an approach which we thought might offer a solution to these limiting factors. Traveling through the area, one often sees a row of potatoes alternating with a row of maize. According to the 1979 census, no less than 25% of the area in potatoes in the department of Chimaltenango consists of such an association (3). The small literature of this association (1, 10, 17) generally reports favorable results so a series of experiments were set up with the following objectives:

1. Better understand the relationship between maize and potatoes when grown in association.

2. See how the system could be managed for more efficient production.
3. See what other vegetables could be grown in association with the maize without adversely affecting maize yields while still producing acceptable yields of vegetables of marketable quality. Special attention would be given to those vegetables such as broccoli and cauliflower with stable prices.
4. Determine what management practices such as relative dates of planting, maize variety, spacing, and population would contribute to higher yields and maximum return per investment in labor and capital. The maize program of ICTA (the Guatemalan Government research agency) had developed shorter-stature, shorter season maize varieties which seemed promising for association with vegetables.

MATERIALS AND METHODS

Research on the maize-potato system began in 1978 (12). In 1979, a more extensive range of experiments were run in the departments of Chimaltenango and Sacatepequez using a sequence of different vegetables, among them potatoes-carrots, broccoli-carrots, and cauliflower-carrots, combining them with both local (tall, long season) and improved (short stature, early maturing) maizes at different spacings to allow higher populations of associated vegetables. Maize populations were always maintained at 41,000 plants per hectare as in the farmers' systems. As all of the experiments were performed on farmers' fields, every effort was made to maintain maize yields at the levels farmers customarily obtained. In 1980, more emphasis was given to the role of beans in the systems, either using climbing beans or substituting bush beans for one of the vegetables in the association. Experiments were located on soils of the series Tecpan and Cauque (20), both extensively used for vegetable production in the departments of Chimaltenango, Sacatepequez, and Guatemala[2]. The two soils, both of which would be considered Typic Eutrandepts in the U.S. Soil Taxonomy (18) (Mollic endosols in the FAO system) are deep, well-drained permeable soils formed from volcanic ash. The Tecpan series is of coarser texture and generally occupies flat to gently rolling (up to 15% slopes) (15). However, because it is more extensive closer to Guatemala City, because water for irrigation is sometimes available on the slopes, and slopes often provide more favorable microclimate for vegetables (improved air drainage, less risk of frosts, and reduced evaportranspiration on north-facing slopes), the Cauque series probably accounts for more area presently in vegetables than the Tecpan series. Both soils[2] are characterized by high water-holding capacity, which, combined with relatively low evapotranspiration at higher altitudes and good management practices, can make sufficient water available for crop growth for several months after the end of the rainy season (Figure 4). Thus, it is not unusual to find crops of cabbage being harvested three months after the end of the rainy season or crops of maize in the Chimaltenango Valley being planted three months before the start of the rainy season, which extends from May to October. Rainfall varies from 900 to 1200 mm per year while frosts principally occur in the month of December but may occur as late as March.

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2 No experiments were carried out in the department of Guatemala because the government research agency had no program in this area until the end of 1980.

Varieties, plant population, and fertilization for different species used are shown in Table 1. For intercropping systems, population of cabbage, broccoli, and carrots were 2/3 of monoculture populations with fertilizer reduced accordingly. With potatoes, two intercropping systems were used, with populations and fertilization at monoculture levels in the system where potatoes were planted in 1.2 m rows. Production was evaluated for quality standards prevailing at local markets or freezing plants where the produce was sold. Prevailing prices for 1980 are given in Table 1. In the case of potatoes, net income was determined at different price levels, ($4, and $9 per cwt.) since these have varied considerably in the hihglands over the past year. Costs for various operations were determined from farm records, maintained by ICTA (16). Other prices are those prevailing in 1980.

Land Equivalent Ratios (L.E.R.) and Harvest Diversity Indices (H.D.I.) were calculated according to procedures given by Wiley (19) and Menegay, Hubbel, and William (14), respectively.

Results

Results for each species will be discussed separately although in many cases, experiments were done with a sequence of two species:

1. White potatoes (*Solanum tuberosum* L.)

Results of experiments in the township of Tecpan Guatemala (elevation 2200-2400 m) and the Chimaltenango Valley (elevation 1776 m) are presented in Table 2. Tecpan Guatemala is a major potato producing area; the Chimaltenango valley is not although the government research station located in the valley does a considerable amount of potato research.

The results support the conclusion of Kass and Chew (12) that when maize yields in monoculture were below 4500 kg/ha, association with potatoes increases maize yields. As expected, potato yields were greater at the higher elevation. Both increasing the space between maize rows and using a shorter stature maize increased potato yields, the effect of the two factors together resulting in statistically significant yield increases at both elevations. The effect of using a shorter stature maize was more significant at the lower elevation where competitive effects were probably greater since the maize was further developed at the time of potato planting. Thus, potato yields were 64-87% of monoculture yields at the higher elevation as compared to 23 to 62% at the lower elevation. On the other hand, the shorter stature maize performed better at the lower elevation; but it benefitted from the association with potatoes at the higher elevation. In fact, at the lower potato prices, its use would only be justified at the higher elevations, using the wider spacing. It can also be seen that at the higher elevations, no associated system was as profitable as a pure stand of potatoes; at the lower elevation, when potato prices were low, it would be more profitable to plant maize and beans than any system involving potatoes - a result which perhaps explains, or at least confirms, the present practice of farmers in the area.

2. Broccoli

The chief advantages of broccoli over potatoes are a more stable and higher price and a lower labor requirement. Agronomically, it did not generally perform as satisfactorily as potatoes in association with maize, with both head size and yields being reduced by more than 60% with respect to monoculture in some cases (Table 3). However with such low production, the association could still be profitable since maize yields were generally quite high when broccoli yields were low and heads were still of acceptable size for freezing. Where competition could be reduced (sites 1 & 4) by transplanting the broccoli before the maize had developed fully (less than two months after planting) or after it had reached physiological maturity (six months after planting), performance was quite acceptable with over 50% of monoculture yields and no reduction of head size. At the lower elevation, where maize is normally planted three months before the onset of the rains, it was possible to clear the field of a short season maize, associated with potatoes, two months before the end of the rainy season, permitting a monoculture broccoli crop which produced over 10,000 kg/ha. At a potato price of $0.132 per kilo, such a system could produce profit of $1300 on 0.6 has, after producing maize and purchasing beans for subsistence. Even at a $0.088/kg potato price, profit would still be $750.

A further study was carried out at site 2 to determine effects of associating climbing beans with maize on broccoli yield and quality. As broccoli rows were harvested individually; competitive effects could be seen more clearly since center rows (there were three rows of broccoli between each maize row) should be less affected than rows next to the maize plants. These results are shown in Table 4. It can be seen that while all factors reduce yields, the effects are not as great as the actual reduction of yield which was 57% while head size was only reduced by 28%. At least half of the reduced yields in intercropping, therefore, must be attributed to reduced populations, which were only 67% of the monoculture levels. Rather than compensating for reduced populations by producing larger heads, the broccoli grown in association with maize, due to competitition from the latter produced heads smaller than those produced in monoculture.

3. Cabbage

Results with cabbage would appear to confirm the relative rarity of finding cabbage associated with maize in the central highlands of Guatemala. The cabbage-maize association would appear to combine the disadvantages of the two previously discussed associations: the detrimental effects on yield and quality shown by broccoli and the unstable and often low prices shown by potatoes. While wholesale prices in Guatemala City varied from $0.4 to $0.9 per kilogram during 1979, on farm prices remained a fairly constant $0.035. The highest yields obtained when cabbage was planted following beans or peas between 1.8 m rows of maize were 20,000 kg/ha while up to 85,000 kg/ha were obtained in monoculture. Fewer than 75% of the plants in the association produced marketable heads while mean head weight was only 60% that of monoculture. Planting cabbage at dates when competition with maize was less would perhaps have been more successful but such a planting date, i.e., May or June, was never tried.

4. Cauliflower

Only one experiment was done with cauliflower, using the locally produced cultivar, a large-headed Erfurt type, in 1979. The freezing company no longer accepts this type, accepting only Christmas White hybrid because of internal curd color. With shorter stature maize, yields of 3978 kg/ha or about 63.76% of monoculture yield were obtained. Monoculture yields were only about 75% of those obtained in other trials (5) however. With local maize, only 2671 kg/ha or 44% of monoculture yields. Maize yields were disappointingly low in the experiment, being only 2823 and 1436 kg/ha for the local and short stature maizes respectively which was nevertheless higher than their monoculture yields (2587 and 1319 kg/ha respectively). However, some farmers who took up the system in 1980 claimed to have obtained up to 6900 kg/ha of cauliflower and 3500 kg/ha of maize using the local varieties but these yields were not confirmed.

5. Carrots

Carrots were only used as a second crop in the experiments, following potatoes, cauliflower, broccoli, or beans and were generally planted in the month of September or later. Possibly because of heavy rains in this month, carrots planted earlier were observed to be heavily attacked by *Alternaria*, which proved difficult to control.

Since carrot seeds germinate slowly, carrots planted in September would not have three leaves until the month of October, when rainfall is considerably less and competition from the maturing maize is reduced. It was thought that the maize might offer some protection to the germinating carrot seed but as can be seen from Table 5, carrot yields were generally quite high in monoculture, where there was no protection for the germinating seed. In fact the carrot yields in the associations which were generally of high enough levels to be profitable, were in one site, less than 25% of monoculture yields. With the exception of one site, carrot production in association rarely surpassed 50% of monoculture yields, which were quite good in all sites but one, eventhough 67% of the seed and fertilizer used in monoculture were used in the association. Thus, the return per dollar invested is less in the associated system than in the monoculture system but is nevertheless still profitable. Carrot prices, though low, show greater stability than cabbage and potato prices, perhaps because of greater domestic demand, which would appear to be less elastic than that of potatoes and cabbage, the bulk of which are exported. Carrot quality did not appear to be affected adversely by association with maize (Table 5), (the percent marketable carrots never being significantly smaller, and in some cases being slightly greater than the monoculture levels).

Discussion

In the total of 13 situations in which vegetables were associated with maize, the vegetables were, in all cases but one, the crop which suffered most from the association. As can be seen from Table 6, where the ranges of percent monoculture yields are presented, the percentages of monoculture vegetable yields obtained are always less than percentage of pure stand populations used. Taking this difference as a measure of competition from the maize, it would be concluded that competitive effects could reduce vegetable yields by as much as 50%. Although it would appear that the cases of least competitive effects from maize occurred with root crops (potatoes and carrots), the cases of greatest competitive effects also occurred with these crops. Broccoli demonstrated a smaller variation in yield reduction than either other root crops, and the greatest yield reduction attributable to competition from maize with the cole crops was less than 50%. Use of a shorter stature, quicker maturing maize almost always had a beneficial effect on vegetable yields. The chief objection to the use of such a maize for these systems is that the yields are lower than farmers are used to obtaining, but are generally above the levels needed for subsistence. Net income was always higher with the use of the shorter stature maize since the increased vegetable production was of higher value than the maize production lost.

Although there was some evidence of reduction of quality in broccoli, cabbage and carrots resulting from association with maize, these reductions were less in evidence when competition from maize could be reduced somewhat by planting the vegetables at times when competition from maize would be less. These times were as early or as late in the cycle of maize development as would be possible while still supplying adequate moisture to the vegetable crops. Worse competitive effects were noted when vegetable crops were planted more than two months after maize planting or more than three months previous to maize harvest. One of the problems with late planting is that the vegetables will exhaust soil moisture for the next season's crops. This would not be a problem if the succeeding crops are not planted until the rains start, which is the case for most crops except maize and beans. It should be noted that most of the yields of the vegetable crops were expressed in terms of marketable product rather than total product - thus the effects of quality on yields appeared greater than if unmarketable produce had been included.

In spite of all the negative effects of maize competition on vegetable quality and yields, most of the associations produced greater profit, return per unit capital, and return per unit labor than sole pure crop maize. The only cases where they failed to do so were in the case of cabbage and in the case where potato prices were low. The total capital and labor requirements were much higher than the sole crop maize however and slightly lower than the sole crop vegetables. However, the profitability return per unit labor, and return per unit capital are greater for the monoculture vegetables than for the associated vegetables, even though these systems often produced higher maize yields than sole crop maize. However, the value of such a maize yield increase was generally quite small in comparison to the value of the vegetable yield decrease and in the case of the shorter stature maizes, yield levels of maize were quite low in both the monoculture and associated systems.

From the experience of growing carrots, cabbage, cauliflower, potatoes, and broccoli in association with maize in the central highlands of Guatemala, the following conclusions could be reached:

1. Although the associations generally reduced yields of vegetables by a factor greater than that by which populations were reduced in the association, the yields were still sufficiently high to bring a reasonable profit so long as vegetable prices did not fall to very low levels. Profits were lower than with pure stands of vegetables but higher than with pure stands of maize.
2. Maize yields were rarely significantly decreased by the association and in some cases significantly increased. This effect was probably due to the maize making use of the high levels of fertilizer applied to the vegetable crops.
3. Competition effects on the vegetables could be reduced by using a shorter stature, quicker maturing maize and/or by planting the vegetables less than two months after the maize was planted or less than three months before the maize was harvested.

4. It might be worthwhile to repeat the experiments using lower populations of vegetable crops, for example, 50% of monoculture levels, as this would reduce the costs of vegetable production.

LITERATURE CITED

1. CROCIONI, 1951. Rilievi sulla Consociazione della Patata con girassole e granoturco e sulle reciproche influenze fra le piante consociate. Annali della Sperimentazione Agraria 5:441-451.

2. DIRECCION GENERAL DE ESTADISTICA. 1964. Censo Agropecuario de Guatemala. Guatemala.

3. DIRECCION GENERAL DE ESTADISTICA. 1979. Censo Agropecuario de Guatemala. (In Press).

4. DUARTE, R.W., P.E. HILDEBRAND, and S.R. RUANO A. 1976. Tecnología y estructura agrosocioeconómica del minifundio del Occidente de Chimaltenango. ICTA. Guatemala. 79 pp.

5. FUENTES, D.E. and DONALD C.L. KASS. 1980. Estudios de fertilidad y espaciamiento de cruciferas en el altiplano central de Guatemala. Programa Cooperativo Centroamericano para Mejoramiento de Cultivos Alimenticios (PCCMCA) XXVI Reunión Anual Guatemala.

6. GLADWIN, C. 1980. The future of corn production in Guatemala: How farmers decide. International Fertilizer Development Center.

7. INSTITUTO NACIONAL DE COMERCIALIZACION AGRICOLA (INDECA). 1981. Comercialización de brócoli (algunos aspectos). Dirección de Servicios Técnicos. Departamento de Tecnología de Mercadeo. Guatemala.

8. ______________ (INDECA). 1979-80. Comercio Internacional y Noticias de Mercado Interno de Productos Agrícolas, 2o, 3o trimestre de 1979; 1o, 2o trimestre de 1980. Guatemala DOC-DIST-07/79, 10/79, 08/80 and 011/80.

9. INTERNATIONAL RICE RESEARCH INSTITUTE IRRI. 1974. Multiple Cropping in IRRI; Annual Report 1973. p. 15-34.

10. KASS, D.C.L. 1978. Polyculture Cropping Systems: review and analysis. Cornell University International Agriculture Bulletin No. 32. Ithaca, N.Y. 69 p.

11. KASS, D.C.L. 1981. Aumento de la productividad y rentabilidad de los sistemas de producción tradicionales del valle de Chimaltenango. XXVII Reunión Anual, PCCMCA. Santo Domingo, Dominican Republic. SC 21-1-18.

12. KASS, D.C.L. and F. CHEW. 1980. Efecto de cultivos asociados y niveles de fertilización sobre rendimiento de maíz en el altiplano central de Guatemala. XXVI Reunión Anual del PCCMCA. Guatemala.

13. DOPEZ YOS, T.R., R. GAMBOA, J.J. GUTIERREZ G. and D.C.L. KASS. 1980. Alteraciones en la milpa tradicional del altiplano de Guatemala para aumentar la producción de cultivos asociados. XXVI Reunión Anual del PCCMCA, Guatemala.

14. MENEGAY, M.R., J.N. HUBBELL, and R.D. WILLIAM. 1978. Crop Intensity Index: A research method of measuring land use in multiple cropping. Hortscience 13(1):8-12.

15. SIMMONS, C.S., TARANO, J.M. and Z.J.H. PINTO. 1959. Clasificación de reconocimiento de los suelos de la República de Guatemala, Guatemala, Ministerio de Agricultura. 1959. 996 p.

16. SAMAYOA, ESSAU G., J.T. LOPEZ YOS, G. PELAEZ G., and PETER SHIRES. 1978. Registros económicos de producción en milpa (maíz, frijol, haba), trigo, papa, y frijol de suelo. Chimaltenango. 1977. ICTA. Socioeconomía Rural 30 p.

17. TOBON, J.I. Comportamiento de algunos sistemas agrícolas tradicionales a varias prácticas de producción en el oriente antioqueño. Medellín, Colombia, ICA Regional 4. Boletín de Investigación No. 47. 1977. 98 p.

18. SOIL CONSERVATION SERVICE. 1975. Soil Taxonomy. USDA Agric. Handbook No. 436. 754 p.

19. WILLEY, R.W. 1979. Intercropping - Its importance and research needs. Part I. Competition and Yield Advantages. Field Crop Abstracts 32(1):1-10.

20. WYLD, J.T. and A.H. NATARENO. 1978. Caracterización de los suelos de 8 ensayos de finca realizados durante 1978 en Patzicia, Tecpan, Zaragoza, Comalapa y Santiago Sacatepequez, municipios de la Subregión V-4 Guatemala, 1978. 38 p.

21. MONTENEGRO, J..M.S. and J. OVALLE A. 1980. Comercialización de repollo en Guatemala. Diagnóstico DOC-DIST-DTM-03-80. Dirección de Servicios Técnicos, Departamento de Tecnología de Mercadeo. INDECA. Guatemala. 35 p.

Table 1. Varieties, densities, fertilizer levels, pesticides, and prevailing prices for crops used in experiments.

Crop	Cultivar	Density (plants/ha)x10^3	Fertilization (kg/ha)	Fungicides Product - amount applied per ha	Number of applications	Insecticides Product - amt. applied per ha - No. of appl.	Prevailing price-1980 $/kg
Broccoli	Green Duke	55-monoculture 37-associated	20-20-0:600 Urea: 300 Solubor: 8	Dithane M-45 PCNB	(seedbed only) (seedbed only)	Orthene - 1 kg - 1 Thiodan - 1 l - 1 Belmark - 1 l - 1 Sevin(80-WP) 1kg - 1	0.308
Carrot	Royal Chauntenay	500-monoculture 333-associated	15-15-15:1333 Complete foliar: 3 l	Anthracol 2 kg-3		Thiodan - 1 l - 3 Furadan - 40kg - 1	0.100
Cauliflower	Local Erfurt	27.7-monoculture 18.5-associated	Same as broccoli	Same as broccoli		Same as broccoli	0.26
Cabbage	Green Boy	62.5-monoculture 41.6-associated	16-20-0:1227	Dithane M-45 2 kg-2		Same as broccoli	0.035-0.08
White Potato	Loman	37-monoculture and associated in wide rows 27.7-associated with maize in traditional spacing	20-20-0:1227	Dithane M-45 2 kg-4 Cobrethane 2 kg-2 Anthracol 2 kg-2		Volaton (2.5%) 50 kg - 2 Thiodan 1 l - 1 Metasystox 1 l - 1 Belmark 1 l - 1	0.088-0.198
Maize	Local Improved: Don Marshall Chanin	41 Traditional spacing 1.2x1m, 5 seeds per hill Wide rows: 1.8x0.67 m 5 seeds per hill	20-20-0:500 Urea:200	None		Furadan (5%) 40 kg - 1 Volaton (2.5%) 36 kg - 1	0.176
Climbing Bean	Local	50-low elevations 16.3 (high elevations)	Nothing applied to beans per se				0.66
Bush Bean	ICTA Selection: San Martín Vaina blanca	200-monoculture 67-associated	16-20-0:250	Dithane M-45 2 kg-1 Anthracol 2 kg-2		Thiodan 1 l 1 Metasystox 1 l 1 Sevin 1 kg 1	0.66

Table 2. Yields and economic returns of potatoes associated with maize of different plant types in two different spacing arrangements at sites of different elevation in the central highlands of Guatemala.

	Western region				Chimaltenango Valley			
Site altitude	2300				1770			
(Meters above sea level)	1026				914			
Annual rainfall (mm)	15.4				17.8			
Mean annual temp. °C	April 10				February 16			
Date of maize planting	May 25				May 25			
Date of potato planting								
Maize plant type	Local, tall, 8 month		Improved, short, 6 month		Local, tall, 8 month		Improved, short, 6 month	
Maize spacing	1.2 x 1.0 m	1.8 x 0.67 m	1.2 x 1.0 m	1.8 x 0.67 m	1.2 x 1.0 m	1.8 x 0.67 m	1.2 x 1.0 m	1.8 x 0.67 m
Maize yield in monoculture (kg/ha)	5766 a		2442 b		3137 ce		2735 c	
Maize yield (kg/ha)	3778 b	4427 b	3042 b	3070 b	4309 de	4387 d	3059 c	2760 c
Potato density (pl/ha)	27,777	37,000	27,777	37,000	27,777	37,000	27,777	37,000
Yield of potatoes, more than 7 cm long, kg/ha	17,474 h	20,098 gh	18,298 h	23,643 fg	4,734 m	8,700 mk	12,668 k	12,663 k
Yield of potatoes more than 7 cm long in monoculture	----	27,159 f	----		----	20,293 j	----	
Land equivalent ratio	1.29	1.50	1.92	2.17	1.58	1.98	1.74	1.63
Crop following potatoes	Carrots	Carrots	Carrots	Carrots	Climbing bean	----	Bush bean	Bush bean
yield (kg/ha):	2151	5595	2820	6679	941	1002	1040	1239
Net income per hectare:								
Potatoes at $.198/kg	$1903	$2481	$2018	$2989	$320	$832	$1110	$952
Potatoes at $.088/kg	-18	270	6	516	-202	124	-286	-441
Labor requirement: (man-days/ha)	411	442	435	458	336	389	444	465
Net income of monocultures: potatoes followed by carrots or beans:								
Potatoes at $.198/kg	3953	3953	3953	3953	2343	2343	2343	2343
Potatoes at $.088/kg	966	966	966	966	111	111	111	111
Net profit of traditional maize-bean association ($/ha)	321	321	189	189	246	246	-222	-222

Values followed by same letter do not differ significantly at $p = 0.05$.

Table 3. Evaluation of production systems involving broccoli and maize associations at four sites in the highlands of Guatemala (1979-1980)

Site number	1.		2.		3.		4.	
Site altitude(meters above sea level)	2115		2150		2140		1760	
Crop sequence associated with maize	Broccoli followed by carrot		Broccoli followed by lentil		Bush bean followed by broccoli		White potato followed by broccoli	
Yearly rainfall (mm)	1149		1034		949		914	
Date of maize planting	April 10		April 27		April 24		February 16	
Date of broccoli transplant	May 27		July 27		July 25		August 29	
Maize type	Tall, local 8 month	Short, 6 month improved	Tall, 8 month local, without climbing beans	Tall, 8 month local with climbing beans	Tall, local 8 months	Short, improved 6 months	Tall, local 8 months	Short, improv 6 months
Maize yield (kg/ha)	3675	1225	4886	4250	5023	4900	3966	3304
Yield of 1st. quality broccoli, kg/ha	4125	4978	3010	2784	1816	2551	4825	10503
Yield of 1st. quality broccoli in monoculture	7808	7808	7560	7560	5631	5631	9983	9983
Land equivalent ratio	1.48	1.75	1.54	1.36	1.19	1.28	2.05	2.43
Mean weight per head of broccoli (g) associated with maize	220	230	102	98	73	91	178	195
Mean weight per head of broccoli in monoculture (g)	210	210	150	150	126	126	200	200
Number of broccoli cuts to 95% yield	6	6	11	11	9	9	4	4
Yield of other crops in sequence:								
Beans (climbing or bush) kg/ha	---	---	---	192	1230	1233	---	---
Carrots (kg/ha)	11270	14857	---	---	---	---	---	---
White potatoes (kg/ha)	---	---	---	---	---	---	12560	17171
Lentils	---	---	599	534	---	---	---	---
Harvest diversity Index (H.D.I.)	2.92	2.24	2.90	3.24	3.11	2.97	2.94	2.32
Net income ($/ha)	1582	1682	833	690	726	909	1062	2902
Total labor need (man-days per ha)	296	289	243	232	291	295	437	510
Net income from a manzana (0.69 ha) after producing or purchasing maize and beans required for subsistence:	550	582	135	36	61	187	293	1562

Table 4. Effect of row position of broccoli and presence of climbing beans on yield factors of broccoli grown in association with maize.

Location of broccoli row	Yield (kg/ha)	% of plants producing 1st. quality heads	Mean weight per head (g)	Percent yield obtained by 6th cutting
Associated with maize without climbing beans				
Central rows	3280	88.6	111	72.4
Site rows (adjacent to maize plants)	2618	76.9	98	57.8
Associated with maize with climbing beans				
Central rows	2820	77.3	108	61.2
Side rows	2446	80.0	92	67.3
Broccoli in pure stand	7560	89.4	154	83.7
Significance by F test at 5% level	Row position significant Position of beans not significant	No effect significant	Row position and presence of beans significant Interaction not significant	Interaction between position and presence of beans significant

Table 5. Production and economic evaluation of systems including carrots associated with local and improved maizes at four sites in the central highlands of Guatemala (1979-1980).

Altitude of site above sea level:	2240 m		2115 m		2180 m		2180 m	
Rainfall during growth period of carrots (mm)	257		384		306		118	
Previous crop in sequence (also grown in association with maize)	White potato		Broccoli		Cauliflower		Bush beans	
Maize type	Local (Tall, 8 month)	Improved (Short, 6 month)	Local (Tall, 8 month)	Improved (Short, six month)	Local (Tall, 8 month)	Improved (Short, six month)	Local (Tall, 8 month)	Improved (Short, 6 month)
Maize yield (kg/ha)	4427	3070	3675	1225	2823	1436	4748	3156
Total yield of carrots in monoculture (kg/ha)	11776 a		28760 e		32199 f		19694 j	
% of total carrot yield marketable (longer than 5 cm)	88.0 c		94.6		90.0 h		86.2	
% of total carrot yield longer than 10 cm	50.0		63.6		51.8		70.5	
Total yield of carrots grown in association (kg/ha)	6186 b	7463 b	12079 d	15382 d	4484 g	8341 g	37188 k	24213 k
% of total carrot yield marketable (longer than 5 cm)	90.0 c	89.0 c	92.4	94.8	62.0 h	92.0 h	91.6	89.0
% of total carrot yield longer than 10 cm	30.6	37.5	59.1	72.9	33.0	73.3	76.5	73.9
Land equivalent ratio (L.E.R.) of maize-carrot	1.29	1.89	1.38	1.65	1.23	1.34	2.68	1.75
Number of bags carrots per hectare	155	170	261	320	100	237	708	448
Value of carrots[1/] ($/ha)	826	906	1391	1705	533	1263	3773	2387
Value of previous crop ($/ha)[2/]	2652	3120	1270	1533	705	1050	616	609
Value of maize ($/ha)	779	540	646	216	496	253	839	544
Net income ($/ha)	1154	1428	1522	1568	67	811	3090	1597
Harvest diversity index (H.D.I.)	2.53	1.89	1.94	2.24	2.92	2.38	1.78	1.97

Values followed by same letter do not differ significantly at $p = 0.05$

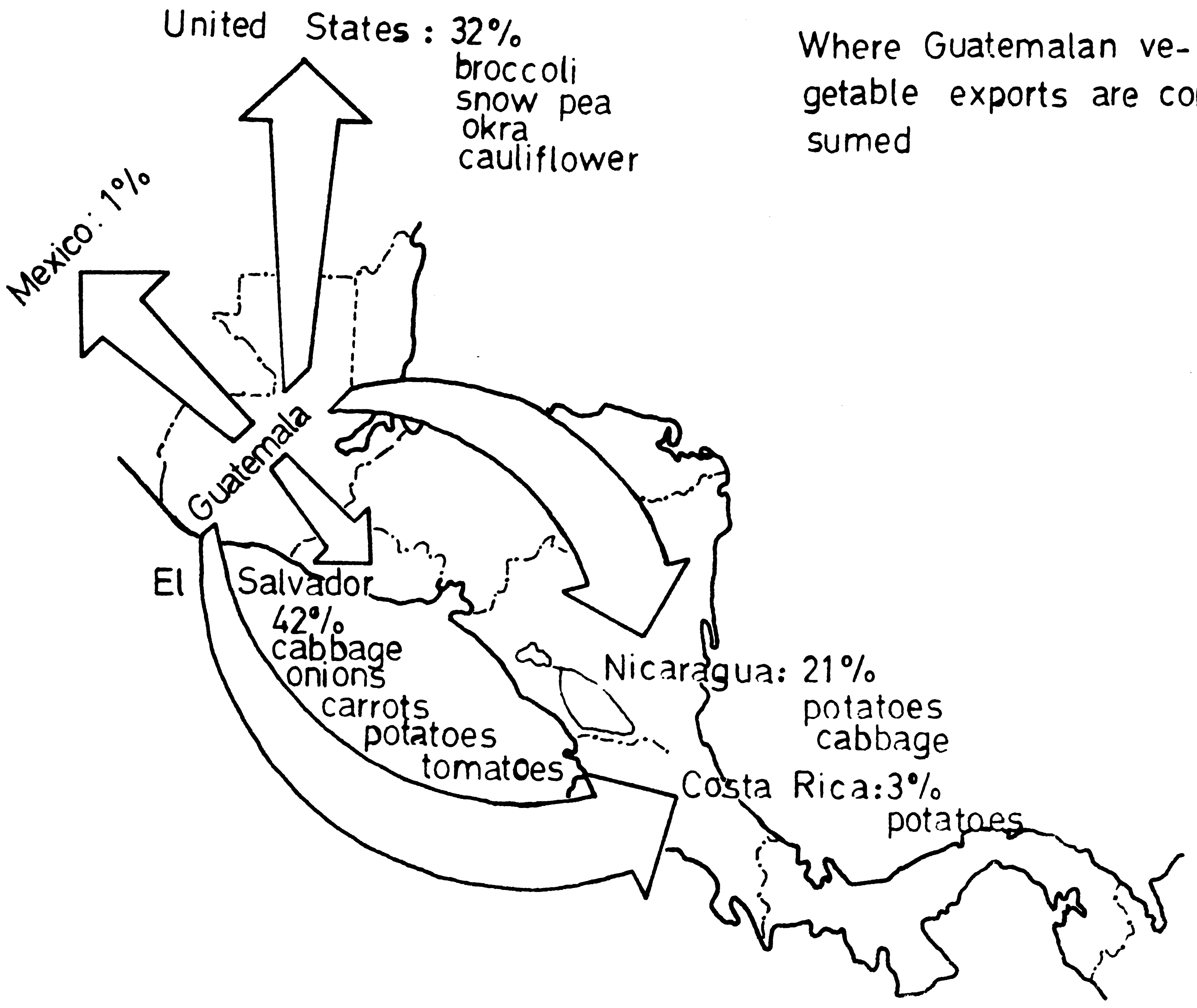
1/ Prevailing carrot price in first semester of 1980 was $5.33 per bag in terminal market of Guatemala City. Transport costs deducted in calculation of net income.

2/ Potatoes evaluated at $0.132/kg (mean of prevailing prices). All other prices as in Table 1.

Table 6. Ranges of percent monoculture yields obtained with different vegetable crops in association with maize in Guatemalan Central Highlands 1979-1980.

Crop	% pure stand population used	Maize type	% pure stand yields	% pure stand maize yields
Potatoes	75	Local	16.3-23.3	65.4-137.3
	75	Improved	62.5-67.3	111.8-124.5
Potatoes	100	Local	42.8-74.0	76.7-154.2
	100	Improved	62.4-87.0	100.9-125.7
Broccoli	67	Local	27.6-51.5	91.3-151.2
	67	Improved	38.7-58.9	89.0-110.1
Cauliflower	67	Local	44.0	109
	67	Improved	63.8	109
Carrots	67	Local	11.2-173.2	76.7-109.0
	67	Improved	26.6-109.0	61.7-124.5
Cabbage	67	Local	23.5	91.7

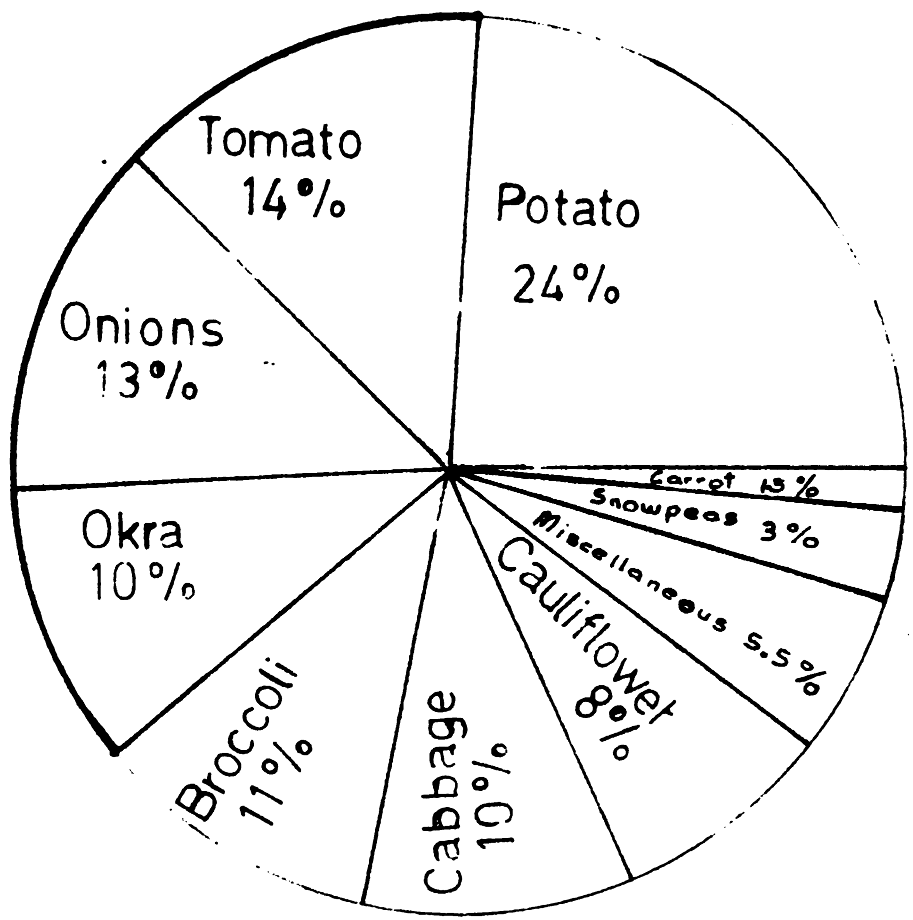
Figure 1:



Where Guatemalan vegetable exports are consumed

Figure 2 :

VEGETABLES EXPORTED FROM GUATEMALA 1979



Total value: $ 9,568,180 per year

Source: National Institute of Agricultural Marketing (INDECA): Report of International Trade

Figure 3: Location of potato producing townships in Guatemala (1964 Agricultural Census)

▤ : Townships in which monoculture predominates

▨ : Townships in which there is some association of potatoes with maize

▥ : Townships in which most of the potato production comes from associations

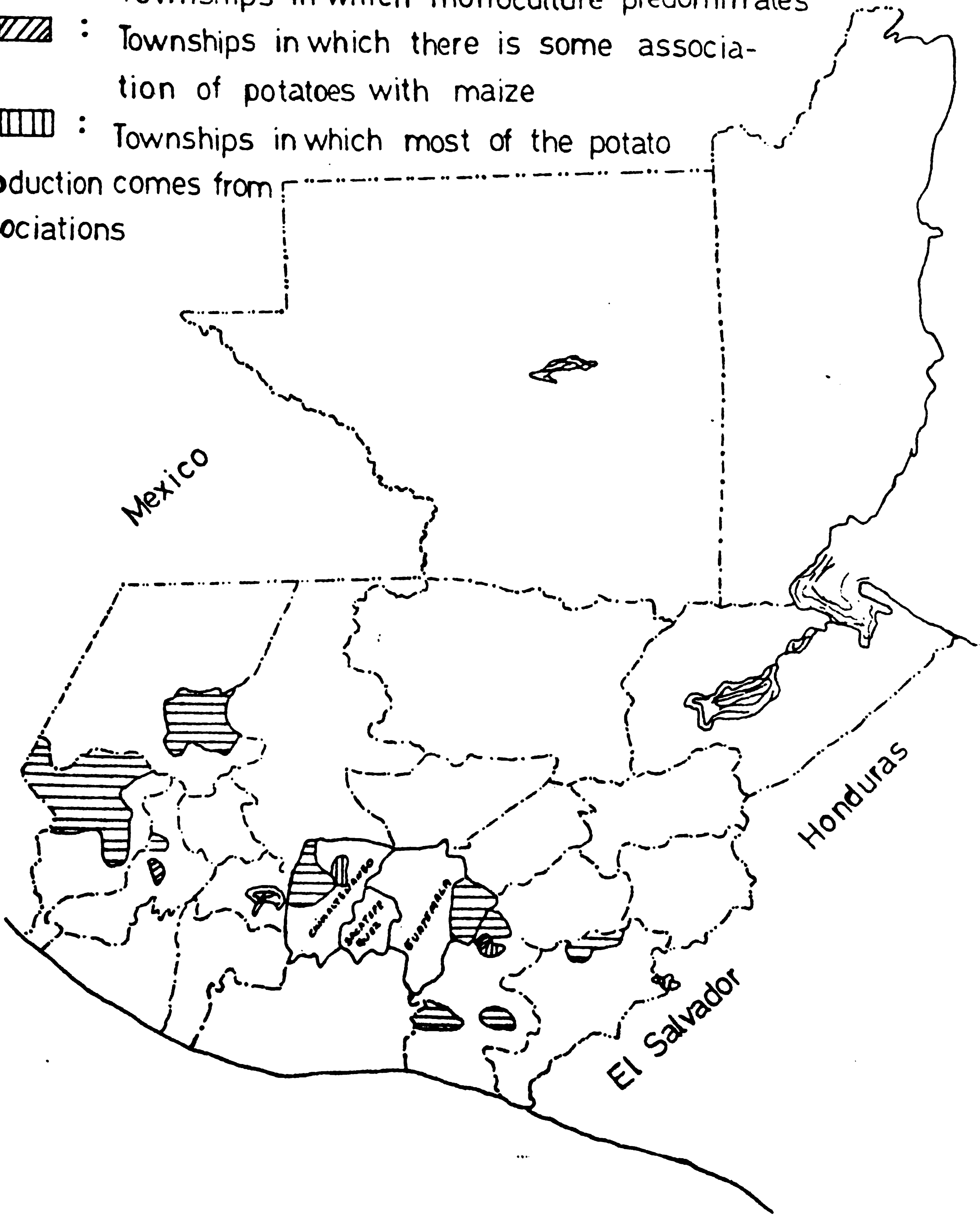


Figure 4: Gravimetric water plotted on soil moisture characteristic curve for three dates follwing end of rainy season at 20 cm depth in a soil of the Tecpan series (typic eutrandept) located at 2300 meters above sea level in the central highlands of Guatemala (1978-79)