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ANALYSIS OF WATER SUPPLIES IN IRRIGATED CROPS - SMALL REGIONS

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Abstract: Analyzing the extraction of water for agricultural use in the study region, of surface and underground origin, the former has decreased (from 37.6 to 34.2%) and the latter has increased (from 62.4 to 65.8%). Climate change has greatly affected the frequency and intensity of rainfall, especially in small regions. In the case of the study municipality, with three types of climates (temperate, warm and semi-warm) and highly eroded semi-arid soil, it has presented problems of water availability. The need arises to decide which would be the appropriate irrigation crops to ensure their maximum production value, subject to the water requirements that ensure their full development. To respond, a linear programming model was formulated under two scenarios. The model is complemented with the criterion of cross elasticities of supply prices, that is, from the point of view of the producer. It was proved that green lucerne, corn, oats and forage sorghum, pastures and meadows, are not feasible due to their water consumption. Historically, crops with the highest production value were Autumn-Winter: forage oats, grass and meadows; Spring-Summer: green forage maize; and Perennials: green lucerne. Substitute crops turned out to be date, taco and African perennial palms. This tool will support decision-making in strategic planning in agribusiness and government policies. The model can be applied to any region.

Keywords: Region, Water, Crops.

JEL codes: C61, D29, Q01.

1. INTRODUCTION

Early experiences in mitigating climate change, with the use of yield enhancement factors, proved that these are not enough. African farmers adopted to improve their yields: improved seeds, specific fertilizers and innovative irrigation and sanitation techniques, depending on the crop. Even so, for medium-term changes in precipitation patterns and daily temperature

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ranges, it showed the need to make more drastic decisions (Adams *et al.* 1990) to ensure feeding. Since 1990, papers have been published that have exposed the devastating effect of changes in rainfall patterns: intensive concentration in one month, change in frequency and intensity, and temporary offset (Abrol *et al*. 1996, Boko *et al*. 2007, Adams *et al*. 1990, Kumar *et al*. 2019).There is general agreement that global warming will be greatest at latitudes between the tropics and the poles. Different models based on various methodologies (time series, econometric and multiregressive) predicted that the effects of global warming would cause increases in daily temperature ranges and changes in the duration of the seasons of the year, according to latitude and altitude, (Prakash, 2011, Maharjan & Joshi, 2013, Kunah, 2018). Prakash formulated a model for traditional crops in Nepal, based on crop response to water stress, which linearly relates changes in crop yields and changes in temperatures and rainfall. Prakash formulated a model for traditional crops in Nepal, based on crop response to water stress, which linearly relates changes in crop yields and changes in temperatures and rainfall. Their results indicated that the temperature increase of 0.7 °C favored rice cultivation over potato, wheat and corn, due to the increased availability of water in historically frozen areas.In the state of Aguascalientes, the increase in temperature was calculated at 0.77 °C (Ledesma *et al*. 2021), which increases the evaporation of surface water.

Siqueiros *et al*. (2016) reported that 80% of the original vegetation cover of the state has been modified due to human settlements with agricultural and livestock activities, causing, to a large extent, around 90% of soil erosion and groundwater scarcity. Surface water evaporates on average 70%.

Since the beginning of the 21st century, Olson et al. (2007) analyzed the state of agriculture and water resources for irrigation in Mexico. Very few alternatives to irrigated agriculture existed, because the level of rainfall only allowed the production of low-value rainfed crops or did not allow rain fed agriculture at all. For this reason, fodder crops were preferred to boost livestock in semi-arid areas. With the Free Trade Agreement (NAFTA), policies to support the competitiveness of agricultural production encouraged the degradation of water resources. Consequently, it was essential to improve the yields of irrigated agriculture and the management of water resources by increasing water use concessions (REPDA 2022; CONAGUA 2019, 2020; INEGI 2017; Table 1), currently reaching the overexploitation of aquifers.

Some proposals from international organizations to meet the food needs of the future establish response capacity as a requirement: build a response system to the spread of risks, modify traditional and current practices, create species resistant to environmental stress, promote cooperation between governments to all levels, and finance projects at the local level that solve specific problems (Kumar *et al*. 2019 and Olowa *et al*. 2011).Therefore, it was chosen to solve the problem at the regional level (city hall) based on the disaggregation of data. Complementary methodologies were used here to find the most suitable traditional and alternative crops in the region given the future scenario of global warming.

To illustrate the present study, the municipality of Jesús María, Ags., Mexico was chosen. The municipality of Jesús María is located at 21° 57' 40'' north latitude and 102° 20' 36'' west longitude, and at an altitude of 1880 m.a.s.l. It has an extension of 499.18 Km2. Its average maximum temperatures range between 7.9 and 26.7 °C, and average annual rainfall of 568.5 mm. In 2011 the rainfall was 275 mm (SMNM 2020). The effects of climate change are increasingly visible within the region. A few years ago, the entity's good climate was conducive to large areas of crops such as vines, as each of the four seasons was well defined: strong heat in summer and intense cold in winter, however, they are becoming more and more blurred. The limits between seasons, the cold is less intense and the rainy season is less and less stable and there are precipitation levels that exceed the standard levels. The soil is made up of land from the Cenozoic age of the Tertiary period, which are: planasol, regosol, lithosol, xerosol and feozem, being for agricultural use for the most part. Because the soil is badly eroded, basic fertilizers provided by the government are used. The suitable fertilizers for crops are composed of nitrates, sulfates, carbonates, potassium and some metals.

Crops have specific coefficients associated with the heat-humidity balance or evapotranspiration necessary for their development (FAO 1990; Steduto 2012; SAGARPA 2012, SIAP 2017, 2020 a, b, c; SIAP 2022, Ledesma *et al*. 2021).From Public Registry of Water Rights (REPDA *in* Spanish), water concessions for agricultural use are of the surface and underground type. To date, 30659080.71 (65.8%), 20171917.71 (34.2%) m^3 are extracted, respectively, the values from 2003 to 2021 appear in table 1(UAM 2019).

2. OBJECTIVES OF STUDY

The objective of the study is to find a tool that, based on past decisions regarding irrigated crops, determines the appropriate crops given the water requirements during the development of the plant and the availability of water, whether of surface or underground origin, depending on the characteristics of the region, *see* Table 1.

3. METHODOLOGY

A model with a linear structure was formulated from the producer's point of view. The objective function maximizes the value of production, subject

to restrictions on water requirements for agricultural use, which ensure the complete development of the crop given the availability of the resource, and the best yields, including improvement factors such as the use of improved or native seed, health, fertilizers, mechanization and modernization of irrigation. In general, claims are not reported in irrigated crops. The model allows finding the feasible production volumes that satisfy the stated conditions. Data from surface and underground sources according to the Public Registry of Water Rights (REPDA *in* Spanish) were used. Two scenarios were considered: *E1*, minimum water requirements with optimal water saving technology, fertilizers, labor and capital necessary for the development of crop *i* in year *t*. *E2*, maximum water requirements with irrigation technology and the rest unchanged.
Let:

x_{it} is the production volume of crop *i* in year *t*.

a_{it} the coefficient of crop *i* in relation to its yield in year *t*.

b_{it} the coefficient of crop *i* in relation to its water requirement in year *t*.

p_{it} is the price per produced volume unit of crop *i* in year *t*.

Objective Function:

$$Max_x \left\{ \sum_{i=1}^{41} p_{it} x_{it} \mid Ej_{x_{it}} \right\}, \; i = irrigation\ crops,\ t = 2003,\ \ldots,\ 2020;\ j = 1,2.$$

restricted to:

$$\sum_{i=1}^{41} a_{it} x_{it} \mid Ej_{x_{it}} \le historical\ maximum\ yields\ in\ the\ region\ without\ loss$$

$$\sum_{i=1}^{41} b_{it} x_{it} \mid Ej_{x_{it}} \le available\ water\ in\ year\ t$$

$$x_{it} \mid Ej_{x_{it}} \le historical\ maximum\ level\ without\ loss_i$$

$$x_{it} \mid Ej_{x_{it}} \ge 0$$

Alternative crops. Incorporating palm trees in the optimization model, dates can be considered an alternative perennial crop. For those interested in delving into the genomic characteristics of this crop and its varieties, consult Khalifa *et al*. (2016) and Solomon *et al*. (2017a,b).Planting together with citrus trees is recommended (FAO 1990). Date is very versatile, of high quality (Mexico, Iraq, Iran) and fodder (India, Saudi Arabia, Iraq, Syria).

Oil palm (Torres and Peña, 2015): All varieties of palms are suitable for similar soil and climate. Minimum and maximum water requirements for the entire development of the plant were reported between 97.41 and 33.152 m^3/Ton per year, (Palacios and Pinzón, 2015; Báez, 2018).The reader who wants to explore experiences in the production of this crop as biofuels can consult Zapata *et al*. (2007).

The maximum yields of the African palm tree were reported after 20 years in other countries, with production costs between 330 and 600 USD/Ton, (Mosqueda et al. 2021).

The advantage, in addition to the consumption of water and basic fertilizers, has been in the non-degradation of the land as occurs in other crops (blue agave, alfalfa, sorghum, wheat, corn and fodder oats).

Table 1: Annual withdrawal of water for agricultural use by origin, [m^3].

Year	*Underground*	*Superficial*	*Year*	*Underground*	*Superficial*
2003	17346394.3	10458051	2013	19028391.3	10487163
2004	17914894.3	10458051	2014	19099847.7	10487163
2005	17914894.3	10473051	2015	19162633.7	10487163
2006	17914894.3	10473051	2016	19213133.7	10487163
2007	17939081.3	10473051	2017	19406333.7	10487163
2008	18011081.3	10473051	2018	19826013.7	10487163
2009	18145481.3	10473051	2019	20171917.7	10487163
2010	18145481.3	10473051	2020	20171917.7	10487163
2011	18195481.3	10487163	2021	20171917.7	10487163
2012	18297481.3	10487163			

4. RESULT AND DISCUSSION

The results of the model appear in tables 2 and 3, indicating which crops are feasible and which are not. That is, the feasible ones can effectively use the area's water resources. With a tight control in the distribution of the liquid in forage triticale in green and potato crops.

Table 2: Crop feasibility. Notation: F feasible, NF not feasible.

A-W	*E1*	*E2*	*S-S*	*E1*	*E2*
Chard	F	F	Chard	F	F
GFO	NF	NF	Amr	F	F
Btr	F	F	GFO	NF	NF
B	F	F	Eggp	NF	NF
GFB	NF	NF	Btr	F	F
Onion	F	F	B	F	F
Crndr	F	F	B S	F	F

contd. table 2

A-W	*E1*	*E2*	*S-S*	*E1*	*E2*
Cabb	F	F	S P	F	F
Clf	F	F	Onion	F	F
L	F	F	Pea	F	F
R	F	F	D Ch	F	F
FTG	F	NF	G Ch	F	F
Carrot	F	F	Crndr	F	F
P&M	NF	NF	Cabb	F	F

Green fodder oats is not feasible in both autumn-winter and spring-summer season crops. Green feed barley, forage sorghum in green, eggplant, corn, green lucerne, camedor and Ornamental palms, Pastures and meadows, seasonal and perennial.

Table 3: Crop feasibility. Notation: F feasible, NF not feasible.Continuation of Table 2

S-S	*E1*	*E2*	*S-S*	*E1*	*E2*
Clf	F	F	Carrot	F	F
Spn	F	F	PRNN	E1	E2
G B	F	F	G L	NF	NF
Corn	NF	NF	Peach	F	F
Beans	F	F	Apple	F	F
L	F	F	Nut	F	F
FMG	F	F	Tuna	F	F
G C	F	F	Grape	F	F
Potato	F	NF	P&M	NF	NF
Ccm	F	F	Date	F	F
R	F	F	AP	F	F
FSG	NF	NF	CP	NF	NF
R T	F	F	OP	NF	NF
G T	F	F	HP	F	F

Also taking into account the elasticities in the feasible crops, it can be seen from tables A1 and A2 that swiss chard is a crop with Giffen elasticity (1.3323), and coriander (2.7916) and cauliflower (2.1197) are adequate substitute crops.Similarly for the other feasible.

For non-feasible crops, green forage oats, pastures and meadows are inelastic. Green barley is elastic. And as substitute crops are coriander (0.5342, 0.8596, 2.3530) and cauliflower (0.4056, 0.6527, 1.7866), respectively.

From tables A3, A4, A5 and A6, the feasible Spring-Summer crops: beetroots (0.7707), cabbage (0.6763), corn (0.0497), beans (0.4552), green forage maize (0.2969) and grain maize (0.9866) had inelastic elasticities. The rest were elastic.

The non-feasible crops with inelastic elasticity were corn (0.0497), the others were elastic: green fodder oats (2.0628), eggplant (14.1667) and forage sorghum in green (2.2196). As substitute crops could be sweet potato (0.0908, 3.4745, 3.2072, 3.3274), respectively.

From tables A7 and A8, the non-feasible perennial crop with inelastic elasticity was pastures and meadows (0.6067). Elastics: green lucerne (1.3993), camedor palm (16.1386) and ornamental palm (1.1542).

Suitable substitute crops were apple (3.1269, 5.9401, 101.2804, 28.1648), prickly pear (1.2213, 2.3200, 39.5567, 11.0002), and date (0.5745, 1.0915, 18.6097, 5.1751), respectively.

5. CONCLUSION

Feasible and suitable crops were found to be substituted, ensuring the water requirements for the complete development of the plant. The maximum value of the basket of seasonal and perennial crops was ensured. The model can be replicated to other regions.

Appendix A

Table A1: Cross supply price elasticities. Autumn-Winter seasonal crops.

A-W	*Chard*	*GFO*	*Btr*	*B*	*GFB*	*Onion*	*Crndr*
Chard	1.3323	0.2549	1.0012	1.3284	1.1230	1.6734	1.7134
GFO	2.0138	0.3854	1.5134	2.0079	1.6974	2.5295	2.5899
Btr	1.1876	0.2273	0.8925	1.1841	1.0010	1.4918	1.5274
B	1.5371	0.2941	1.1552	1.5326	1.2956	1.9307	1.9768
GFB	1.2474	0.2387	0.9374	1.2437	1.0514	1.5668	1.6043
Onion	1.3601	0.2603	1.0221	1.3561	1.1464	1.7084	1.7492
Crndr	2.7916	0.5342	2.0979	2.7834	2.3530	3.5065	3.5902
Cabb	1.3170	0.2520	0.9897	1.3131	1.1101	1.6542	1.6937
Clf	2.1197	0.4056	1.5929	2.1134	1.7866	2.6624	2.7260
L	1.1592	0.2218	0.8712	1.1558	0.9771	1.4560	1.4908
R	1.2743	0.2439	0.9577	1.2706	1.0741	1.6006	1.6389
FTG	0.5363	0.1026	0.4030	0.5347	0.4520	0.6736	0.6897
Carrot	1.6642	0.3185	1.2506	1.6593	1.4027	2.0903	2.1403
P&M	2.0603	0.3942	1.5483	2.0542	1.7366	2.5878	2.6496

Table A2: Cross supply price elasticities. Autumn-Winter seasonal crops. Continuation of Table A1

A-W	*Cabb*	*Clf*	*L*	*R*	*FTG*	*Carrot*	*P&M*
Chard	3.1511	1.5925	1.7186	1.0419	1.0527	1.4896	0.4102
GFO	4.7631	2.4072	2.5978	1.5749	1.5913	2.2517	0.6201
Btr	2.8090	1.4196	1.5320	0.9288	0.9384	1.3279	0.3657
B	3.6356	1.8374	1.9828	1.2021	1.2146	1.7187	0.4733
GFB	2.9504	1.4911	1.6091	0.9755	0.9857	1.3947	0.3841
Onion	3.2169	1.6258	1.7545	1.0636	1.0747	1.5207	0.4188
Crndr	6.6028	3.3369	3.6011	2.1832	2.2059	3.1213	0.8596
Cabb	3.1150	1.5743	1.6989	1.0299	1.0406	1.4725	0.4055
Clf	5.0134	2.5337	2.7343	1.6577	1.6749	2.3700	0.6527
L	2.7418	1.3857	1.4953	0.9065	0.9160	1.2961	0.3569
R	3.0140	1.5233	1.6438	0.9966	1.0069	1.4248	0.3924
FTG	1.2684	0.6410	0.6918	0.4194	0.4237	0.5996	0.1651
Carrot	3.9361	1.9893	2.1467	1.3015	1.3150	1.8607	0.5124
P&M	4.8730	2.4627	2.6577	1.6112	1.6280	2.3036	0.6344

Table A3: Cross supply price elasticities. Spring-Summer seasonal crops

S-S	*Chard*	*Amr*	*GFO*	*Eggp*	*Btr*	*B*	*B S*
Chard	3.0767	0	0.6644	0.6133	0.5172	4.6426	3.1790
Amr	ND	ND	ND	ND	ND	ND	ND
GFO	9.5527	0	2.0628	1.9041	1.6057	14.4144	9.8703
Eggp	71.0713	0	15.3474	14.1667	11.9464	107.2423	73.4345
Btr	4.5852	0	0.9901	0.9140	0.7707	6.9188	4.7377
B	5.1175	0	1.1051	1.0201	0.8602	7.7221	5.2877
B S	6.5965	0	1.4245	1.3149	1.1088	9.9537	6.8158
S P	16.0898	0	3.4745	3.2072	2.7045	24.2786	16.6248
Onion	8.7709	0	1.8940	1.7483	1.4743	13.2348	9.0625
Pea	11.4968	0	2.4827	2.2917	1.9325	17.3480	11.8791
D Ch	5.1323	0	1.1083	1.0230	0.8627	7.7443	5.3029
G Ch	6.3673	0	1.3750	1.2692	1.0703	9.6079	6.5790
Crndr	6.7437	0	1.4563	1.3442	1.1336	10.1759	6.9680
Cabb	3.3978	0	0.7337	0.6773	0.5711	5.1271	3.5108
Clf	9.9185	0	2.1418	1.9771	1.6672	14.9664	10.2483
Spn	4.7867	0	1.0337	0.9541	0.8046	7.2229	4.9459
G B	11.9302	0	2.5762	2.3780	2.0054	18.0019	12.3269
Corn	8.8064	0	1.9017	1.7554	1.4803	13.2884	9.0993
Beans	2.3521	0	0.5079	0.4689	0.3954	3.5492	2.4303
L	9.0113	0	1.9459	1.7962	1.5147	13.5975	9.3109
FMG	1.6756	0	0.3618	0.3340	0.2816	2.5283	1.7313
G C	6.4803	0	1.3994	1.2917	1.0893	9.7784	6.6958
Potato	6.1132	0	1.3201	1.2185	1.0276	9.2244	6.3164
Ccm	5.9609	0	1.2872	1.1882	1.0020	8.9946	6.1591
R	5.4144	0	1.1692	1.0793	0.9101	8.1701	5.5945
FSG	10.1461	0	2.1910	2.0224	1.7055	15.3098	10.4835
R T	4.9934	0	1.0783	0.9953	0.8393	7.5347	5.1594
G T	8.7140	0	1.8817	1.7370	1.4647	13.1489	9.0037
Carrot	9.7781	0	2.1115	1.9491	1.6436	14.7546	10.1033

Table A4: Cross supply price elasticities. Spring-Summer seasonal crops. Continuation of Table A3

S-S	*S P*	*Onion*	*Pea*	*D Ch*	*G Ch*	*Crndr*	*Cabb*
Chard	0.9944	1.8527	0.3397	1.4555	0.8970	0.7829	0.6124
Amr	ND	ND	ND	ND	ND	ND	ND
GFO	3.0874	5.7524	1.0546	4.5190	2.7851	2.4306	1.9014
Eggp	22.9700	42.7978	7.8462	33.6209	20.7209	18.0837	14.1463
Btr	1.4819	2.7611	0.5062	2.1691	1.3368	1.1667	0.9127
B	1.6540	3.0817	0.5650	2.4209	1.4920	1.3021	1.0186
B S	2.1320	3.9723	0.7282	3.1205	1.9232	1.6784	1.3130
S P	5.2002	9.6890	1.7763	7.6114	4.6910	4.0940	3.2026
Onion	2.8347	5.2817	0.9683	4.1492	2.5572	2.2317	1.7458
Pea	3.7157	6.9232	1.2692	5.4387	3.3519	2.9253	2.2884
D Ch	1.6587	3.0905	0.5666	2.4279	1.4963	1.3059	1.0215
G Ch	2.0579	3.8343	0.7029	3.0121	1.8564	1.6201	1.2674
Crndr	2.1796	4.0610	0.7445	3.1902	1.9661	1.7159	1.3423
Cabb	1.0982	2.0461	0.3751	1.6074	0.9906	0.8646	0.6763
Clf	3.2056	5.9727	1.0950	4.6920	2.8918	2.5237	1.9742
Spn	1.5471	2.8825	0.5284	2.2644	1.3956	1.2180	0.9528
G B	3.8558	7.1841	1.3171	5.6437	3.4783	3.0356	2.3746
Corn	2.8462	5.3031	0.9722	4.1660	2.5675	2.2408	1.7529
Beans	0.7602	1.4164	0.2597	1.1127	0.6858	0.5985	0.4682
L	2.9124	5.4264	0.9948	4.2629	2.6273	2.2929	1.7937
FMG	0.5415	1.0090	0.1850	0.7926	0.4885	0.4263	0.3335
G C	2.0944	3.9023	0.7154	3.0656	1.8893	1.6489	1.2899
Potato	1.9758	3.6812	0.6749	2.8919	1.7823	1.5555	1.2168
Ccm	1.9265	3.5895	0.6581	2.8198	1.7379	1.5167	1.1865
R	1.7499	3.2605	0.5977	2.5613	1.5786	1.3777	1.0777
FSG	3.2792	6.1098	1.1201	4.7997	2.9581	2.5816	2.0195
R T	1.6139	3.0069	0.5513	2.3622	1.4558	1.2705	0.9939
G T	2.8163	5.2474	0.9620	4.1222	2.5406	2.2172	1.7345
Carrot	3.1603	5.8882	1.0795	4.6256	2.8508	2.4880	1.9463

Table A5: Cross supply price elasticities. Spring-Summer seasonal crops. Continuation of Table A4

S-S	*Clf*	*Spn*	*G B*	*Corn*	*Beans*	*L*	*FMG*
Chard	1.2871	1.4695	0.5648	0.0174	0.5954	1.0919	0.5451
Amr	ND	ND	ND	ND	ND	ND	ND
GFO	3.9963	4.5625	1.7536	0.0539	1.8487	3.3902	1.6925
Eggp	29.7324	33.9445	13.0465	0.4009	13.7541	25.2231	12.5922
Btr	1.9182	2.1899	0.8417	0.0259	0.8874	1.6273	0.8124
B	2.1409	2.4442	0.9394	0.0289	0.9904	1.8162	0.9067
B S	2.7596	3.1506	1.2109	0.0372	1.2766	2.3411	1.1687
S P	6.7311	7.6847	2.9536	0.0908	3.1138	5.7103	2.8507

Onion	3.6693	4.1891	1.6101	0.0495	1.6974	3.1128	1.5540
Pea	4.8097	5.4910	2.1105	0.0649	2.2249	4.0802	2.0370
D Ch	2.1471	2.4512	0.9421	0.0290	0.9932	1.8214	0.9093
G Ch	2.6637	3.0411	1.1688	0.0359	1.2322	2.2597	1.1281
Crndr	2.8212	3.2209	1.2379	0.0380	1.3051	2.3933	1.1948
Cabb	1.4215	1.6228	0.6237	0.0192	0.6576	1.2059	0.6020
Clf	4.1494	4.7372	1.8207	0.0560	1.9195	3.5201	1.7573
Spn	2.0025	2.2862	0.8787	0.0270	0.9264	1.6988	0.8481
G B	4.9909	5.6980	2.1900	0.0673	2.3088	4.2340	2.1138
Corn	3.6841	4.2061	1.6166	0.0497	1.7043	3.1254	1.5603
Beans	0.9840	1.1234	0.4318	0.0133	0.4552	0.8348	0.4167
L	3.7698	4.3039	1.6542	0.0508	1.7439	3.1981	1.5966
FMG	0.7010	0.8003	0.3076	0.0095	0.3243	0.5947	0.2969
G C	2.7110	3.0951	1.1896	0.0366	1.2541	2.2999	1.1482
Potato	2.5574	2.9197	1.1222	0.0345	1.1830	2.1696	1.0831
Ccm	2.4937	2.8470	1.0942	0.0336	1.1536	2.1155	1.0561
R	2.2651	2.5860	0.9939	0.0305	1.0478	1.9216	0.9593
FSG	4.2446	4.8459	1.8625	0.0572	1.9635	3.6008	1.7977
R T	2.0890	2.3849	0.9166	0.0282	0.9663	1.7722	0.8847
G T	3.6455	4.1619	1.5996	0.0492	1.6864	3.0926	1.5439
Carrot	4.0906	4.6702	1.7950	0.0552	1.8923	3.4703	1.7325

Table A6: Cross supply price elasticities. Spring-Summer seasonal crops. Continuation of Table A5

S-S	*G C*	*Potato*	*Ccm*	*R*	*FSG*	*R T*	*G T*	*Carrot*
Chard	0.4684	0.7115	1.1286	0.8285	0.6731	0.8086	0.8286	0.6363
Amr	ND	ND	ND	ND	ND	ND	ND	ND
GFO	1.4544	2.2090	3.5042	2.5723	2.0898	2.5104	2.5726	1.9755
Eggp	10.8207	16.4351	26.0712	19.1375	15.5481	18.6774	19.1396	14.6975
Btr	0.6981	1.0603	1.6820	1.2347	1.0031	1.2050	1.2348	0.9482
B	0.7792	1.1834	1.8773	1.3780	1.1196	1.3449	1.3782	1.0583
B S	1.0043	1.5254	2.4198	1.7762	1.4431	1.7335	1.7764	1.3641
S P	2.4497	3.7207	5.9023	4.3325	3.5199	4.2284	4.3330	3.3274
Onion	1.3354	2.0283	3.2174	2.3618	1.9188	2.3050	2.3620	1.8138
Pea	1.7504	2.6586	4.2174	3.0958	2.5151	3.0213	3.0961	2.3775
D Ch	0.7814	1.1868	1.8827	1.3820	1.1228	1.3487	1.3821	1.0613
G Ch	0.9694	1.4724	2.3357	1.7145	1.3930	1.6733	1.7147	1.3168
Crndr	1.0267	1.5595	2.4738	1.8159	1.4753	1.7722	1.8161	1.3946
Cabb	0.5173	0.7857	1.2464	0.9149	0.7433	0.8929	0.9150	0.7027
Clf	1.5101	2.2936	3.6384	2.6708	2.1699	2.6066	2.6711	2.0511
Spn	0.7288	1.1069	1.7559	1.2889	1.0472	1.2579	1.2891	0.9899
G B	1.8164	2.7588	4.3764	3.2125	2.6099	3.1352	3.2128	2.4672
Corn	1.3408	2.0365	3.2305	2.3713	1.9266	2.3143	2.3716	1.8212
Beans	0.3581	0.5439	0.8628	0.6334	0.5146	0.6181	0.6334	0.4864

L	1.3720	2.0838	3.3056	2.4265	1.9714	2.3682	2.4268	1.8635
FMG	0.2551	0.3875	0.6146	0.4512	0.3666	0.4403	0.4512	0.3465
G C	0.9866	1.4986	2.3772	1.7450	1.4177	1.7030	1.7452	1.3401
Potato	0.9307	1.4137	2.2425	1.6461	1.3374	1.6065	1.6463	1.2642
Ccm	0.9075	1.3784	2.1866	1.6051	1.3040	1.5665	1.6053	1.2327
R	0.8244	1.2521	1.9862	1.4580	1.1845	1.4229	1.4581	1.1197
FSG	1.5448	2.3463	3.7219	2.7321	2.2196	2.6664	2.7324	2.0982
R T	0.7602	1.1547	1.8317	1.3446	1.0924	1.3123	1.3447	1.0326
G T	1.3267	2.0151	3.1966	2.3464	1.9063	2.2900	2.3467	1.8020
Carrot	1.4887	2.2612	3.5869	2.6330	2.1391	2.5697	2.6333	2.0221

Table A7: Cross supply price elasticities. Perennial crops

PRNN	*G L*	*Peach*	*Apple*	*Nut*	*Tuna*	*Grape*
G L	1.3993	3.4949	5.4946	21.1266	4.7200	3.0764
Peach	0.9790	2.4451	3.8442	14.7809	3.3022	2.1524
Apple	5.9401	14.8358	23.3243	89.6825	20.0363	13.0594
Nut	0.7452	1.8611	2.9260	11.2506	2.5135	1.6383
Tuna	2.3200	5.7944	9.1097	35.0269	7.8255	5.1005
Grape	0.8618	2.1523	3.3838	13.0107	2.9068	1.8946
P&M	1.1525	2.8784	4.5253	17.3997	3.8873	2.5337
Date	1.0915	2.7260	4.2857	16.4787	3.6816	2.3996
AP	0.9538	2.3821	3.7450	14.3997	3.2171	2.0968
CP	0.9465	2.3640	3.7166	14.2905	3.1927	2.0810
OP	0.2434	0.6080	0.9558	3.6752	0.8211	0.5352
HP	0.6753	1.6865	2.6515	10.1950	2.2777	1.4846

Table A8: Cross supply price elasticities. Perennial crops.Continuation of Table A7

PRNN	*P&M*	*Date*	*AP*	*CP*	*OP*	*HP*
G L	0.7366	1.2821	2.4669	23.8588	6.6348	2.0444
Peach	0.5154	0.8970	1.7259	16.6923	4.6419	1.4304
Apple	3.1269	5.4423	10.4718	101.2804	28.1648	8.6786
Nut	0.3923	0.6827	1.3137	12.7056	3.5333	1.0887
Tuna	1.2213	2.1256	4.0899	39.5567	11.0002	3.3896
Grape	0.4536	0.7895	1.5192	14.6932	4.0860	1.2591
P&M	0.6067	1.0559	2.0317	19.6499	5.4644	1.6838
Date	0.5745	1.0000	1.9241	18.6097	5.1751	1.5947
AP	0.5021	0.8738	1.6814	16.2618	4.5222	1.3935
CP	0.4983	0.8672	1.6686	16.1386	4.4879	1.3829
OP	0.1281	0.2230	0.4291	4.1505	1.1542	0.3557
HP	0.3555	0.6187	1.1904	11.5135	3.2018	0.9866

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