EASTERN BROCCOLI SUPPLY CHAIN MODEL

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1-Abstract

Background. Broccoli is a major specialty crop in the United States (U.S.) with a farm-gate value of over $700,000,000. Rise of transportation costs and interest in local and regional food has led to efforts in the Eastern U.S. aiming at insuring a reliable, year-round supply of Eastern-grown broccoli that will be welcomed in East Coast markets.

Data. We collected data on fresh broccoli acreage, yields, production, and transportation costs from emerging broccoli-producing region in the East Coast (Maine, New York, New Jersey, Pennsylvania, Virginia, Maryland, North Carolina, South Carolina, Georgia, Florida) and the mainstream producing regions of California, Arizona in addition to imports from Mexico and Canada. Wherever data were not available, we visited growers and packer/shippers to complement it.

Methods. We develop a mathematical programming model of the Eastern broccoli distribution system to examine optimal production sites and flows for broccoli grown in the East. The optimization model inputs are: seasonal supply in the aforementioned producing regions; seasonal demand in Eastern metropolitan areas; regional production costs, and seasonal transportation costs. Given these inputs, the model minimizes the total costs of producing and transporting broccoli from supply sites to markets and solves for cost-effective seasonal product flows.

Analysis. We use the model to simulate the impact of increased localization (reduction in the weighted average source distance or WASD), increased Eastern acreage and increase in fuel costs on total costs and optimal allocations and flows.

2- Baseline production and transportation model

$$\text{Minimize} \sum_{i}^{ORIG} \sum_{j}^{DEST} \sum_{k}^{SEAS} cost_{i,j} * Q_{i,j,k}$$

Select the quantity shipped from origin *i* to destination *j* in each season *k* that minimizes production and shipping costs

$$Supply\ constraint_{i,k}: \sum_{j}^{DEST} Q_{i,j,k} \leq supply_{i,k}$$

Quantity shipped from location *i* cannot exceed supply capacity

$$Demand\ constraint_{j,k}: \sum_{i}^{ORIG} Q_{i,j,k} \geq demand_{j,k}$$

Quantity received in demand location *j* has to at least meet demand

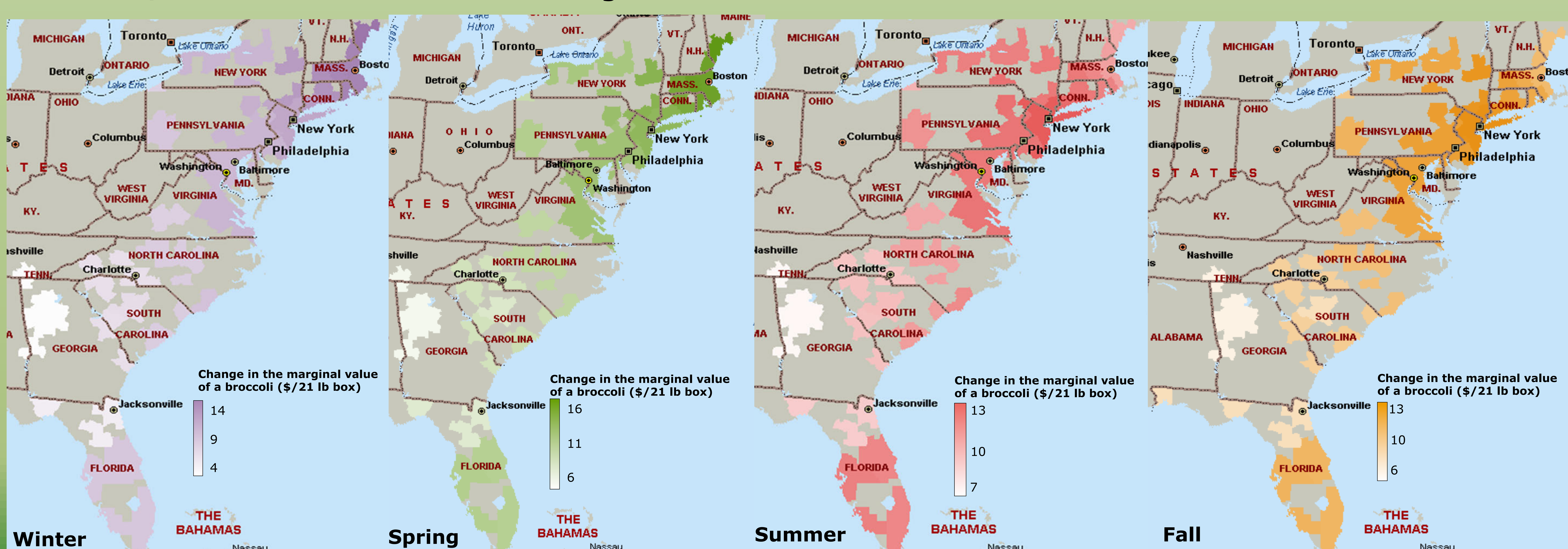
3- Baseline solution and localization scenarios

Table 1. Comparison of Weighted Average Source distance (WASD) and costs under cost-minimization (baseline), distance-minimization and WASD reduction

	Cost-Minimization (Baseline)	Distance-Minimization			Cost-Minimization subject to WASD reduction constraints (1, 5, and 10%)								
					1%			5%			10%		
		value	change	% change	value	change	% change	value	change	% change	value	change	% change
WASD (miles)	1,660	1,488	-172	-10.4%	1,643	-17	-1.0%	1,577	-83	-5%	1,494	-166	-10.0%
Total costs ($ million/ year)	623	745	122	19.6%	629	6	1.0%	657	33	5%	695	72	11.6%
Production Costs	499	609	110	22.1%	505	6	1.2%	531	32	6%	568	69	13.8%
Transportation Costs	124	136	12	9.5%	124	0.2	0.2%	126	1	1%	127	3	2.4%

- An objective of minimizing WASD yields almost 20% higher costs than a cost minimizing objective
- An objective of minimizing costs subject to the constraint of reducing WASD by 1, 5 and 10% increases the system costs by 1, 5 and 11.6% respectively when compared to the baseline (without the WASD reduction constraint)

4- Spatial and seasonal increase in broccoli marginal values in the metropolitan Eastern U.S. due to a 1% WASD reduction/localization under current acreage



5- Scenarios of increase in Eastern broccoli acreage

Fig. 1 Seasonal increase of Eastern broccoli share in Eastern markets under Eastern acreage increase scenarios

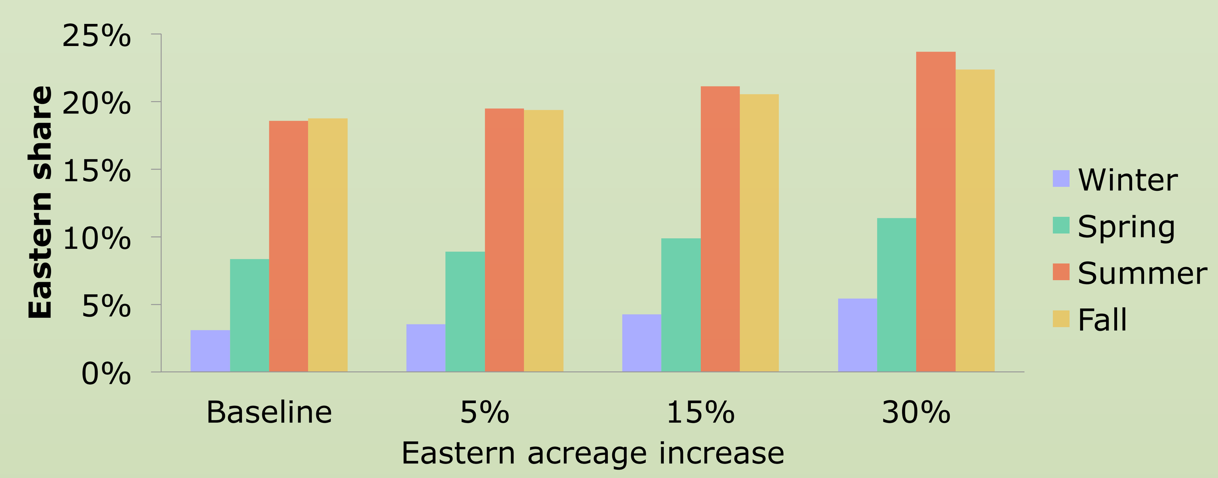
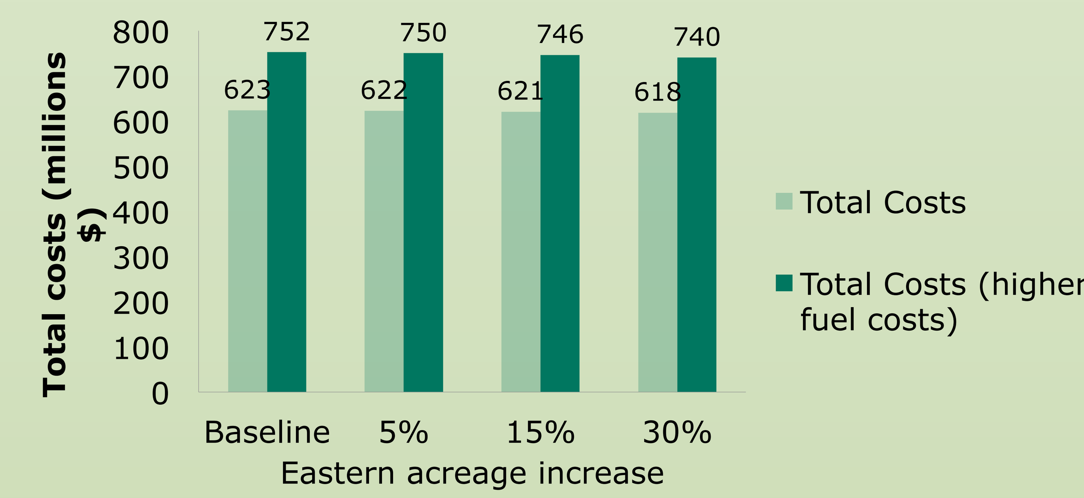


Fig. 2 Total Costs function of increased Eastern acreag



- The additional acreage (1, 15, 30% increase) is allocated to Eastern production regions based on the marginal values (shadow cost) of land obtained from the baseline optimal solution
- The results are similar with (table 3) and without (table 2) fuel cost increase

- Total costs decrease linearly with an increase in Eastern broccoli acreage
- The rate of decrease in total costs under 50% higher fuel costs is more than twice as much as under the baseline fuel costs

Table 2. Scenarios of increase in Eastern broccoli acreage compared to baseline acreage

	Baseline	Eastern acreage increase scenarios (5, 15, and 30%)								
		5%			15%			30%		
		value	change*	% change	value	change	% change	value	change	% change
WASD (miles)	1,660	1,644	-16	-1.0%	1,615	-45	-2.7%	1,569	-91	-5.5%
Total Costs ($ million/year)	623	622	-1	-0.1%	621	-2	-0.4%	618	-5	-0.8%
Production Costs	499	499	0.4	0.1%	500	1	0.2%	501	2	0.4%
Transportation Costs	124	123	-1	-1.%	121	-4	-2.8%	117	-7	-5.7%

* changes are computed with respect to the baseline

Table 3. Scenarios of simultaneous increase in fuel cost (50%) and Eastern broccoli acreage

	Baseline	Baseline with 50% fuel cost increase	Eastern acreage increase scenarios with 50% diesel fuel cost increase								
			5%			15%			30%		
			value	change*	% change	value	change	% change	value	change	% change
WASD (miles)	1,660	1,660	1,644	-16	-1.0%	1,615	-45	-2.7%	1,569	-91	-5.5%
Total Costs ($ million/year)	623	752	750	-2	-0.3%	746	-6	-0.8%	740	-12	-1.6%
Production Costs	499	504	504	0.4	0.1%	505	1	0.2%	505	2	0.4%
Transportation Costs	124	249	246	-3	-1.0%	242	-7	-2.8%	234	-14	-5.7%

* changes are computed with respect to the baseline with 50% fuel cost increase

30% increase in broccoli acreage achieves a WASD reduction of more than 5% (Table 2) without increasing regional marginal values as in the case where a 5% WASD reduction was targeted without an increase in acreage (table 1 and maps in section 4)

6-Conclusion

A 30% increase in Eastern acreage has the potential to reduce the system costs by 5 million dollars a year under current diesel fuel prices and 12 million dollars if fuel prices increase by 50%. It also reduces the system's carbon footprint: WASD is reduced by 5%, which roughly translates into a reduction in diesel fuel usage of 63,000 gallons/year that is equivalent to a reduction in CO_2 emissions of 1.4 million lbs/year.

There is a significant spatial heterogeneity in the marginal value changes under WASD reduction, even for relatively short distances.

One of the model extensions will be to solve for the optimal locations of new broccoli acreage as well as the optimal location of postharvest facilities.

The model results are point estimates. The next stage of the model involves including stochasticity in Eastern broccoli marketable output.

7-Acknowledgements

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