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THE IMPACT ON METROPOLITAN AREAS OF HINTERLAND RESOURCE DEPLETION

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"The life span of intensive development of natural resources is usually short, as increasing inaccessibility of resources lowers the return to capital. Continuous growth is rare, since it requires the creation of urban agglomeration economies — an unlikely occurrence in view of the low labor requirements of natural-resource development. Natural resource zones usually function as enclaves and fail to generate broad economic expansion."[8]

This view of the role of resource development is contrasted with that of Perloff *et al* [6] among others who associate much of historical regional development with resource development.

The focus of this paper is on the association between resource development and metropolitan economies in the mid-continent region of the U.S. The concern is with modeling the potential impacts of a declining resource on adjacent metropolitan areas. The objectives are twofold: (1) to attempt to model the major impacts and (2) to determine if the impacts are significant.

The Resource Problem

Underlying a major portion of what is referred to as the High Plains or Great Plains of the U.S. is the Ogallala aquifer which has provided water for agricultural irrigation for the past 30 years. An approximation of the location of the aquifer appears in Figure 1. About 150 counties and 180,000 square miles overlie the aquifer.

Prior to 1950 the High Plains was a dryland cattle grazing and wheat production area, a reflection of 15-18 inch average rainfall in the area. In the early to mid-1950s the availability of low-cost natural gas as a pumping fuel facilitated a rapid growth of irrigation development. Irrigation brought huge increases in feed grain production which in turn helped create a new activity for the region — cattle feedlots. The six states which contain the major part of the Ogallala aquifer accounted for about 40 percent of the nation's cash receipts from cattle.

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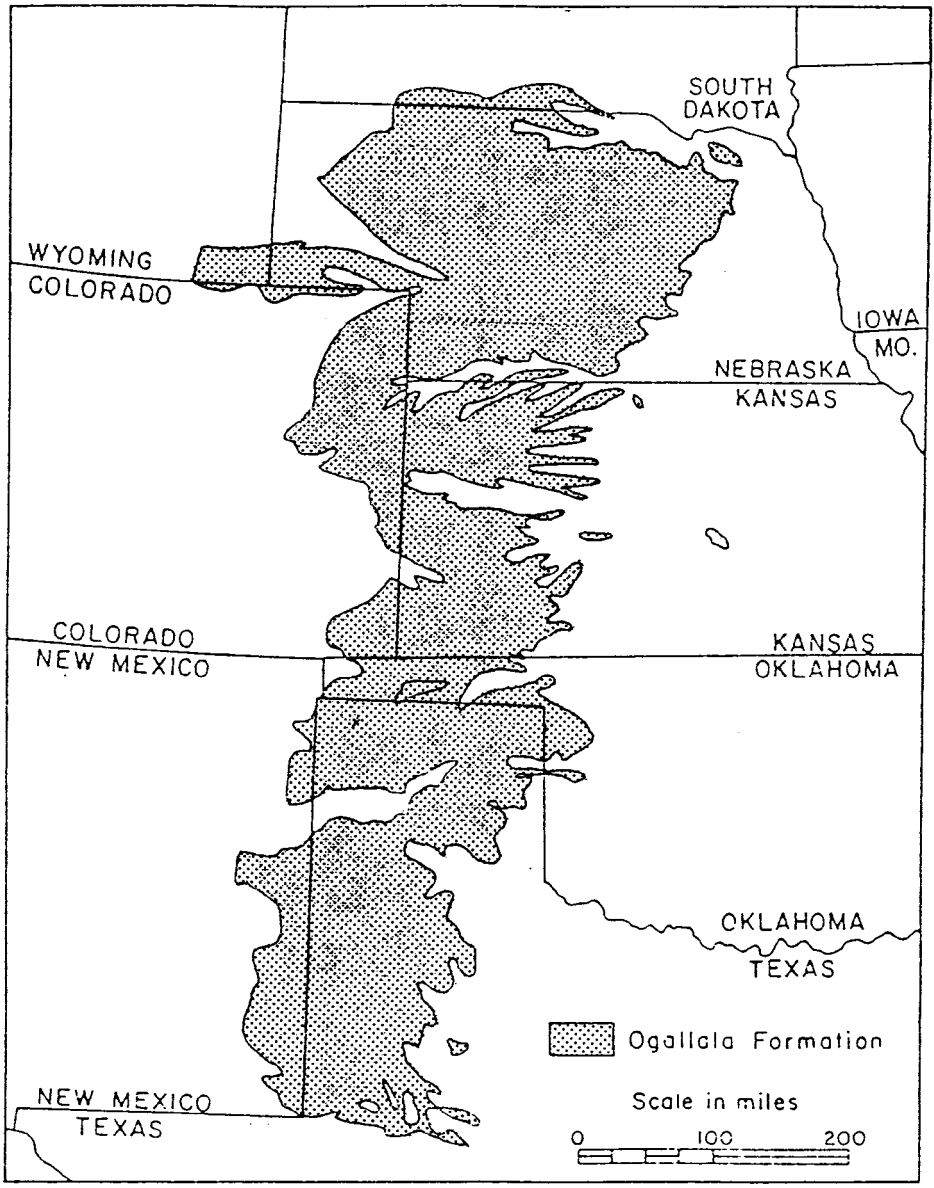

FIGURE 1. GENERALIZED DISTRIBUTION OF THE OGALLALA FORMATION

The feedlot industry has attracted meat packing plants to the region and new plants continue to be built. The world's two largest meat packing plants have been built in the High Plains region of Kansas in recent years. Associated with these developments are, of course, a variety of other linkages to be discussed below.

The Ogallala aquifer, which underlies this substantial development, is being depleted. Irrigated acreage, a trivial amount in 1950, totaled 15 million acres in 1980. Since the aquifer has a very slow rate of recharge, most of the water being pumped for irrigation is essentially being mined since it is a non-renewable resource.

Compounding the declining groundwater levels is the increasing cost and reduced availability of natural gas to operate the pumps. The declining water levels in the aquifer have already resulted in the cessation of irrigation in some areas of the High Plains region.

The Research Problem

A $6 million Economic Development Administration grant financed research on the economic impact of declining groundwater irrigation in the High Plains region of the U.S. That study, completed four years ago, focused largely on the impacted areas, the six-state area and the national economy [4, 5]. A level of impact ignored by that study is that of the metropolitan areas within or adjacent to the Ogallala region. The purpose of this paper is to explore some approaches to modeling the economic impact of reduced irrigation and associated declines in agricultural production on the adjacent metropolitan areas.

Regional economic decline is not a popular spectator sport either for participants or for economic researchers. Abundant literature exists on regional and urban economic growth and development. Little attention has been focused on the economics of decline. Even the substantial attention paid to "lagging" or "distressed" regions is growth oriented. Notable exceptions to the lack of studies of economic decline include impact analyses of military base closures.

Although traditional regional economic impact models have varied in sophistication from simple economic base models to dynamic input-output models or econometric models, they have shared a common orientation. The driving mechanism of these models has been some type of change in external demand for the region's products. The models translate the demand changes into total and component impacts on the urban-regional economy. However, if the initial change is of supplying origin, impacts models are rare.

Selecting an Impact Model

Three different models were considered as potential impact frameworks: economic base models, econometric models, and input-output models. The first two were rejected for reasons explained below.

The econometric model seemed to offer little prospect because of a lack of

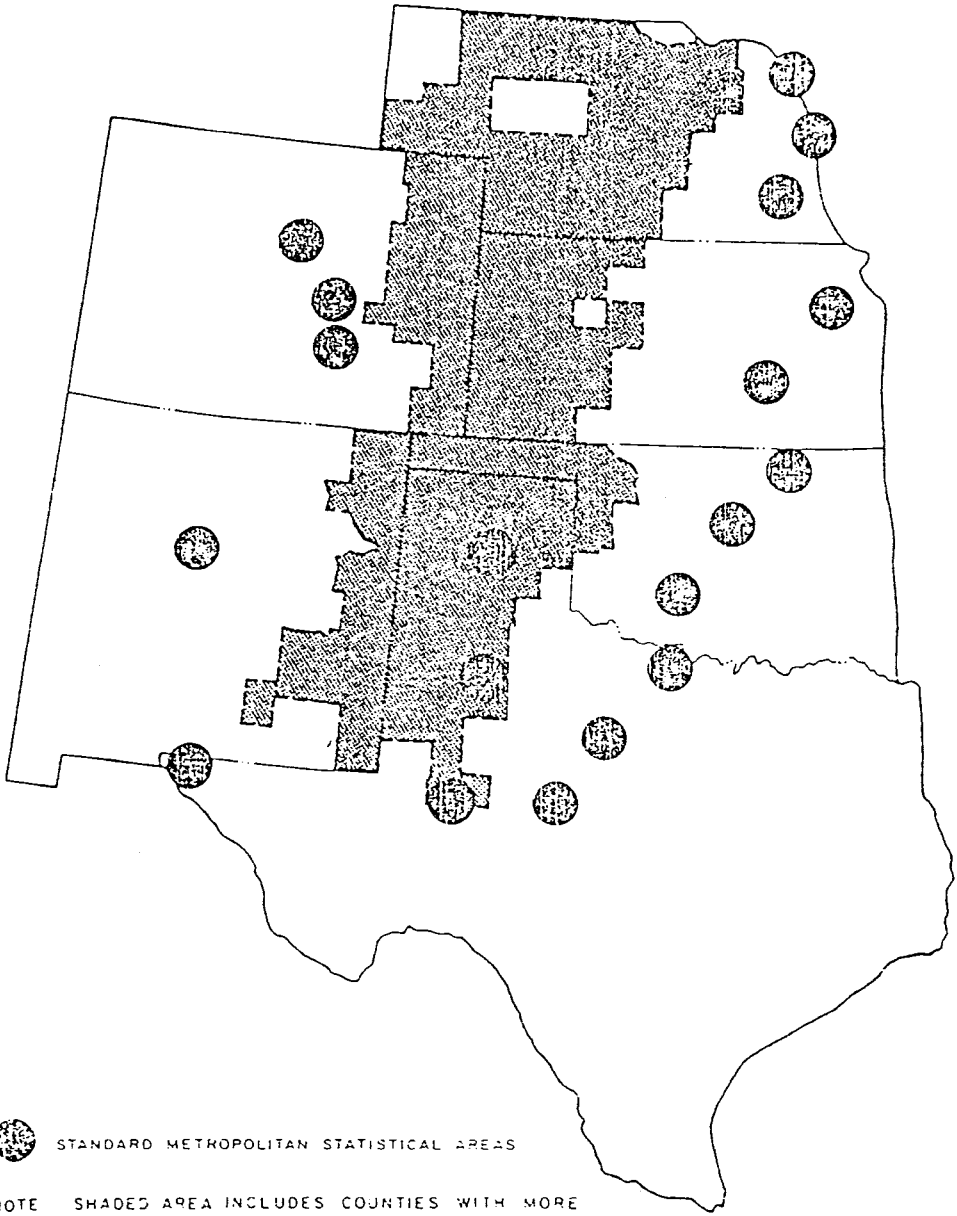

FIGURE 2. CROP PRODUCTION AND POPULATION CENTERS IN TH OGALLALA REGION

time series data to estimate structural relations. Furthermore, in econometric analysis turning points or the switching of phases have not been successfully modeled. In fact times series models more often than not exclude certain periods in estimating model parameters with the rationale that the inclusion of these unusual periods will bias the "normal" structure.

Economic Base Models

The rudiments of the economic base model can be illustrated as follows:

$$Y_i = (E_i - M_i) + X_i$$

Y_i = total income in region i
E_i = local spending (including C, I &G)
M_i = imports into region i
X_i = exports in region i

$$E_i = e_i Y_i$$
$$M_i = m_i Y_i \text{ and } X_i = \bar{X}_i$$
$$Y_i = e_i Y_i - m_1 Y_i + \bar{X}_i$$

$$\therefore \; Y_i = \frac{\bar{X}_i}{1 - e_i + m_i}$$

$$K = \frac{dY_i}{dX_i} = \frac{1}{1 - e_i + m_i} = \frac{Y_i}{\bar{X}_i}$$

An economic base model is a rather limp effort to model the multi-dimensional impacts outlined above. If we were to attempt to implement the model using the location quotient approach (which may have as many weaknesses as the economic base model itself), the results are as indicated in Tables 1 and 2.

The location quotients were calculated as:

$$\frac{R_A/R}{N_A/N}$$

TABLE 1
Location Quotient for Wichita SMSA

Industry	L_{ij}
Agriculture, Forestry and Fisheries	0.541
Mining	1.500
Construction	0.850
Manufacturing	1.046
Furniture, Lumber & Wood Products	0.231
Primary Metal Industries	0.188
Fabricated Metal Industries (incl. not specified metal)	0.947
Machinery, except Electrical	0.731
Electrical machinery, Equipment & Supplies	0.120
Motor Vehicles & Other Transp. Equipment	5.071
Other Durable Goods	0.667
Food and Kindred Products	1.278
Textile Mill and Other Fabricated Textile Products	0.138
Printing, Publishing & Allied Industries	0.938
Chemical and Allied Products	0.462
Other Nondurable Goods (incl. not specified mfg. inds.)	0.548
Railroads & Railway Express Service	0.500
Trucking Service & Warehousing	1.143
Other Transportation	0.786
Communications	0.857
Utilities & Sanitary Services	0.706
Wholesale Trade	1.220
Food, Bakery & Dairy Stores	0.920
Eating & Drinking Places	1.133
General Merchandise Retailing	1.037
Motor Vehicles, Retailing & Service Stations	1.132
Other Retail Trade	1.073
Banking & Credit Agencies	1.118
Insurance, Real Estate & Other Finance	0.939
Business Services	0.941
Repair Services	1.357
Private Households	0.867
Other Personal Services	1.129
Entertainment & Recreation Services	1.125
Hospitals	1.200
Health Services, except Hospitals	1.150
Elementary & Secondary Schools & Colleges	0.987
Government	1.054
Private	0.842
Other Education & Kindred Services	1.250
Welfare, Religious & Nonprofit Membership Organizations	1.200
Legal, Engineering & Miscellaneous Professional Services	0.885
Public Adminsitration	0.782

TABLE 2
Location Quotient for Kansas City SMSA

Industry	L_{ij}
Agriculture, Forestry, & Fisheries	0.351
Mining	0.375
Construction	0.950
Manufacturing	0.876
Furniture & Wood Products	0.308
Primary Metal Industries	0.063
Fabricated Metal Industries (incl. not specified metal)	0.053
Machinery, except Electrical	0.615
Electrical Machinery, Equipment & Supplies	1.200
Motor Vehicles & Other Transp. Equip	0.964
Other Durable Goods	0.815
Food & Kindred Products	0.944
Textile Mill & Other Fabricated Textile Products	0.414
Printing, Publishing & Allied Industries	1.625
Chemical & Allied Products	1.000
Other Nondurable Goods (incl. not specified mfg. inds.)	0.935
Railroads & Railway Express Service	2.250
Trucking Service & Warehousing	1.643
Other Transportation	1.929
Communications	1.071
Utilities & Sanitary Services	1.000
Wholesale Trade	1.585
Food, Bakery & Dairy Stores	0.840
Eating & Drinking Places	0.867
General Merchandise Retailing	1.333
Motor Vehicles Retailing & Service Stations	1.091
Other Retail Trade	1.091
Banking & Credit Agencies	1.118
Insurance, Real Estate & Other Finance	1.364
Business Services	1.059
Repair Services	1.000
Private Households	0.533
Other Personal Services	1.032
Entertainment & Recreation Services	1.000
Hospitals	1.000
Health Services except Hospitals	0.850
Elementary & Secondary Schools & Colleges	0.750
Government	0.732
Private	0.842
Other Education & Kindred Services	1.250
Welfare, Religious & Nonprofit Memberships	1.067
Legal, Engineering & Miscellaneous Professional Services	1.231
Public Administration	1.109

where

R_A = regional employment in industry A
R = total regional employment
N_A = national employment in industry A
N = total national employment

Transportation, trade, F.I.R.E.* and services are economic base components. Among the manufacturing sectors only electrical machinery and printing and publishing are significant exporters. The Wichita SMSA is heavily influenced by aircraft manufacturing. Food processing is the other part of the manufacturing economic base. Trade, finance, and services reflect the regional trade center function of the SMSA.

Such an approach has been widely criticized in the literature and will certainly not be defended here. It is presented by way of contrast with the input-output alternative.

The basic problem with the economic base approach is that it focuses on exports when a significant part of the problem at hand is with reduced imports with a few substitution possibilities.

The economic base approach views imports as a function of regional income or product not as a potential production constraint. Also for the problem at hand such an approach does not facilitate the analysis of structural change.

An Input-Output Approach

In order to model the types of impacts identified above, it is necessary to consider two different effects [see 9]. First, traditional impact analysis focuses on demand changes as "induced by" effects. These are the consequences of changes in the markets for agricultural inputs and associated indirect requirements. Second, reduced agricultural production will reduce imports of grain and livestock products for processing, the "stemming from" effects.

The input-output model has the potential to measure the supply impacts as well as the traditional demand impacts. The impact of a change in demand is a relatively straight-forward traditional use of input-output as described above.

The analysis of supply short-falls in particular sectors is less traditional. Supply restrictions have been analyzed with linear programming when the restricted input was ubiquitously required by the region's industries. The L-P approach was to attempt to maximize regional output or income with a fixed quantity of some input such as energy or water. The problem confronted here is a different type of supply restriction in that it represents reduced input into only one industry (or at most a few) where other industries do not compete for this input.

One possible approach to this problem is to partition the matrix and vectors as follows:

$$\begin{bmatrix} X_r \\ \hline X_u \end{bmatrix} = \begin{bmatrix} A_{rr} / A_{ru} \\ \hline A_{ur} / A_{uu} \end{bmatrix} \begin{bmatrix} X_r \\ \hline X_u \end{bmatrix} + \begin{bmatrix} Y_r \\ \hline Y_u \end{bmatrix}$$

where X_r = output vector of restricted products
X_u = output vector of unrestricted products
Y_r = final demand vector of restricted products
Y_u = final demand vector of unrestricted products
A's = respective partitions of coefficient matrix
$X_u = (1 - A_{uu})^{-1} (A_{ur}X_r + Y_u)$

indicates the output levels for unrestricted products

$$Y_r = [1 - A_{rr} - A_{ru}(1 - A_{uu})^{-1}] X_r - A_{ru} (1 - A_{uu})^{-1}Y_u$$

indicates that the final demands for restricted products are connected by a general linear transformation with the final demands for unrestricted products.

Alternatively, if relatively few sectors are affected by reduced imports, outputs may be restricted by the new lower impact levels where

$$a_{mj}x_j \leq M_j$$

where a_{mj} is the input coefficient for sector j and M_j is the maximum imports available.

Impact Sensitivities

Two metropolitan areas were selected for analysis because of the availability of input-output models. A survey data input-output model was available for Wichita and a secondary data table for Kansas City. Both provided enough detail for the demonstration modeling.

The basic question is whether adjacent SMSA's are likely to be significantly affected by the potential return to dryland agriculture in a significant portion of the Great Plains. At minimum the analysis attempts to identify the potential magnitude of this impact through some sensitivity analysis to determine if a more rigorous analysis would be appropriate. The approach then is to "shock" the economic structure of an SMSA that is adjacent to the H-P region to determine its sensitivity to H-P the current agricultural complex. The simulations are intended to ascertain the general sensitivity, not the precise magnitudes. This approach may then lead to a more rigorous modeling approach once we know something about the sensitivity of the economy to the impact.

Two different scenarios are considered. The first is that crop production declines and sets off a decline in feedlots and local processing. The second scenario is that crop production declines but feedlot cattle operations continue because environmental factors favor a High Plains location. At this point in the research, calibration of demand and supply shifts is tentative.

TABLE 3
Input-Output Simulations

Simulation 1: Contraction in both Grain and Livestock Production (thousands of dollars)

	Induced by Effects	Stemming from Effects
Wichita	637,504	320,072
Kansas City	964,173	297,284

Simulation 2: Contraction in Grain Production (thousands of dollars)

	Induced by Effects	Stemming from Effects
Wichita	221,145	104,001
Kansas City	592,179	223,951

The results of the scenarios appearing in Table 3 show the magnitude of the potential impacts to be substantial. The impacts are relatively different for the two SMSAs. Wichita is relatively more influenced by supply restrictions than Kansas City. Because of its smaller size the relative impact on Wichita is greater.

For the Kansas City economy the results indicate that the greatest impact will be on industries serving H-P agriculture most notably marketing, finance, and transportation. For theWichita economy the most significant impact is on the supply side where industries directly or indirectly using H-P agricultural products will be relatively most affected.

Kansas City, on the other hand, is a major funnel through which H-P agriculture passes because it is a transportation hub with associated communication and financial services.

Structural Change

A third scenario was considered where food processing industries were eliminated when the supply of crops and livestock dropped below a threshold level. The elimination of several industries will change the structure of SMSA economy. An approach to anticipating the significance of this change is via the recalculation of multipliers to determine how the leverage effects have changed. A comparison of output multipliers appears in Tables 4 and 5 indicating reductions in multiplier values particularly for those industries tied to the food processing sectors.

TABLE 4
Output Multipliers for Kansas City:
Current and with Food Processing Sectors Deleted

Sector	Current	Impacted
Agriculture	1.97973	1.92263
Mining	1.6527	1.65107
Construction	1.37819	1.37735
Meat Processing	1.3956	——
Grain Milling	1.26778	——
Balance of Food Products	1.58517	——
Textile & Apparel	1.19419	1.19175
Lumber & Furniture	1.45384	1.44551
Paper	1.19345	1.19077
Printing	1.27175	1.27077
Chemicals	1.27957	1.27347
Petroleum	1.17959	1.17897
Rubber	1.32461	1.29838
Stone, Clay & Glass	1.5452	1.54244
Primary Metals	1.27779	1.27636
Fabricated Metals	1.19467	1.19382
Non-Electrical Machinery	1.19157	1.19061
Electrical Machinery	1.33437	1.33332
Transportation Equipment	1.08293	1.08264
Balance of Manufacturing	1.20297	1.19658
Transportation Services	1.33666	1.33375
Communications & Public Utilities	1.61293	1.59869
Wholesale Trade	1.34664	1.34116
Retail Trade	1.2211	1.21964
Finance and Insurance	1.59833	1.59026
Real Estate & Rentals	1.05722	1.05687
Business Services	1.30466	1.30296
Other Services	1.29187	1.29009
Local Government	1.24185	1.22193
Particulate Matter	1.02418	1.02402
Hydrocarbon	1.03193	1.0319
Sulfur Oxides	1.01042	1.01036

TABLE 5
Output Multipliers for Wichita:
Current and with Food Processing Sectors Deleted

Sector	Current	Impacted
Grain Crops & Soybeans	2.51942	2.48287
Dairy & Poultry Products	2.67643	2.3791
Livestock	2.06912	1.93381
Other Agricultural Products	2.35149	2.31033
Crude Petroleum, NG, & Field Services	1.9145	1.89539
Nonmetallic Mining	1.94276	1.92737
Other Mining	2.10153	2.0846
Maintenance & Repair Construction	2.96887	2.94722
Building Construction	2.5134	2.49058
Heavy Construction	2.48746	2.45609
Special Trade Construction	1.96887	1.94722
Meat & Dairy Products	1.70417	——
Grain Mill Products	1.30019	——
Other Food & Kindred Products	1.44617	——
Apparel & Related Products	1.75907	1.74008
Paper Products, Printing & Publishing	2.0305	2.0056
Chemicals	1.97309	1.93518
Petroleum, Coal, Rubber & Plastic Prod.	1.42056	1,41256
Cement, Concrete, Plaster, Stone, Clay & Glass Prod.	1.64369	1.63062
Primary Metal Products	2.21719	2.18867
Fabricated Structural Metal & Other Metal Products	1.63227	1.61748
Farm, Construction, Food & Other Special Industry Machinery	2.08641	2.06331
Electric Machinery	1.80566	1.79208
Other Machinery	2.10587	2.07825
Aerospace	1.98578	1.96031
Other Transportation Equipment	2.60804	2.58986
Other Manufacturing	1.82016	1.80245
Transportation	1.70411	1.68748
Private Utilities	2.10762	2.08298
Trade	2.52175	2.45766
Finance, Insurance & Real Estate	2.46722	2.40544
Services	2.51013	2.45341
Education	2.60367	2.55825

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