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**Hoes to Herbicides:  
Economics of Evolving Weed Management in the United States**

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## Why Weed Control Matters

Weed control is the most labor-demanding aspect of row-crop agriculture in the absence of herbicides. The past century has seen weed management in the United States evolve from horse-drawn cultivators to broad-spectrum herbicides on herbicide-tolerant crops. Three waves of technological change have driven the evolution. These technologies, by shifting input requirements from labor to capital, have changed the structure of American farms.

This research aims to answer the research question:

➤ **How does new weed control technology affect weed management in row crops and associated farm labor and capital use?**

## Technical Change in Weed Control

Today's weed management technologies evolved through three waves of technological change. In first half of the 20th century, U.S. farmers controlled weeds mechanically. Through the 1930's weed control by hand hoeing and draft-powered cultivation was unchanged from the 1800's.

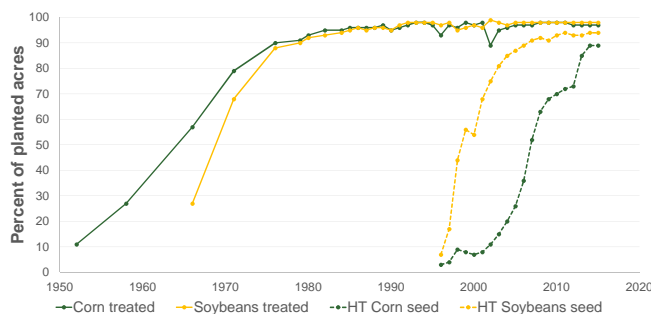
- **1<sup>st</sup> wave: Tractor-drawn cultivators** introduced in the 1940's and 1950's enabled slightly larger acreages to be covered.
- **2<sup>nd</sup> wave: Chemical herbicides** and the advent of tractors with power-takeoff (PTO) that could drive sprayers. During the 1950-95 period, herbicide chemistries were developed to kill weeds by varied toxicological modes of action. Effective weed control in row crops typically required spraying both pre- and post-emergence of the crop.
- **3<sup>rd</sup> wave: Herbicide-tolerant (HT) crops** that are genetically modified to tolerate broad-spectrum herbicides like glyphosate (Roundup™) and glufosinate. Since the 1990's, HT crops have enabled most farmers to drop pre-emergence herbicides, relying on post-emergence sprays only.

Management Method	Labor	Fixed Capital	Variable Capital	Dominant Era
Manual/Animal	Very High	Low	Very Low	1800's – 1930's
Motorized	Medium	High	Medium	1930's – 1960's
Chemical	Low	High	Medium	1960's – Present
Genetic + Chem	Very Low	High	Medium	2000's – Present

### References

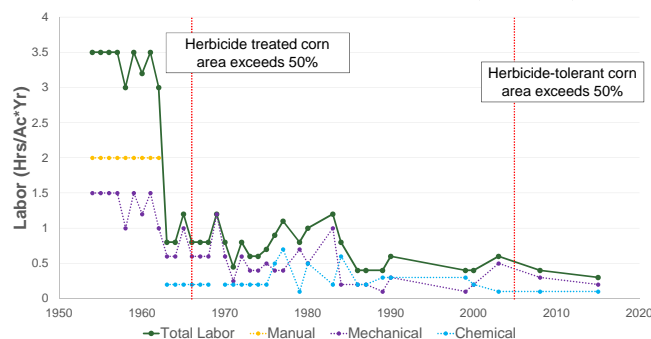
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Osteen, C. D. and J. Fernandez-Cornejo (2013). Economic and policy issues of U.S. agricultural pesticide use trends. *Pest Management Science* 69(9): 1001-1025.  
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Acres of Corn and Soybeans Treated with Herbicides and Herbicide-tolerant Seed



Herbicides were gradually adopted over 30 years (1950-80), while herbicide-tolerant seeds were adopted far more rapidly (1995-2010) (Osteen & Fernandez-Cornejo, 2013; Fernandez-Cornejo & Wechsler, 2016).

Labor for Weed Control in Corn Over Time (California)



Widespread adoption of herbicides reduced labor allocated for weed control by two thirds, as indicated by data on labor in California corn. The adoption of herbicide-tolerant seed led to a modest additional decrease in total labor (Stewart, 2016).

## Model of Cost Minimizing Weed Control

Static cost minimization subject to a yield constraint leads to choice of weed management system where the marginal rate of input substitution (labor for capital) equals the ratio of cost of capital to wage rate. The relative cost of capital to labor will affect the technology chosen so long as weed technology is not of Leontief form, where the labor-capital isoquant is a single point.

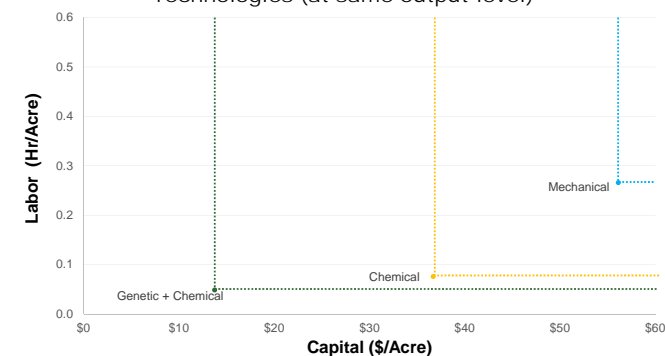
## Empirical Methods

Contemporary weed management systems in U.S. row crops are:

1. **Mechanical** (for non-chemical weed control). Includes 2 field passes with row cultivator and 3 passes with rotary hoe, plus an extra field cultivation in preparation for planting. (Current technology is much more efficient at precision cultivation than tractor-drawn cultivators of the 1940's in the 1<sup>st</sup> wave of 20<sup>th</sup> Century weed control.)
2. **Chemical** (when herbicide resistant weeds require extra herbicide use). Includes 2 weed sprays, pre- and post-emergence of crop.
3. **Genetic + Chemical** (herbicide-tolerant crop). Includes just 1 weed spray post-emergence with glyphosate or glufosinate.

Farm labor and capital costs for were calculated for high levels of weed control on a representative 1,000 acre Midwestern farm. Machinery and labor cost data were obtained from Lazarus (2015) with herbicide cost estimates from Dr. Christy Sprague at Michigan State University.

Isoquants for 3 Current Weed Control Technologies (at same output level)



## Findings & Next Steps

The three technologies represent a nested set of Leontief technologies. For growers who can use any of the three weed control technologies, the Genetic + Chemical system dominates the other two with lower labor and capital costs. The Chemical system is higher cost in both dimensions, but such costs must be faced by grower coping with or seeking to avoid herbicide resistant weeds. This system is still Pareto superior to the Mechanical one for growers who can use it. The Mechanical system has five more field passes, making it more costly in both labor and capital. This system is preferred by producers of organic crops who obtain a price premium that compensates higher production costs.

Future research will examine whether the evolution of U.S. weed control technology has chiefly economized on the scarce factor (labor or capital), consistent with the Induced Innovation Hypothesis of Hayami and Ruttan (1985).