Some Noteworthy Soil Science in Wisconsin

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The impact and benefits of soil science have only partly been documented. Here I highlight four noteworthy soil science achievements from the state of Wisconsin that took place between 1870 and the early 1980s: (i) the first soil map in the United States, (ii) soil erosion control measures in the Coon Creek basin, (iii) soil studies in the forests, and (iv) the establishment of the Antigo silt loam as state soil. These four cases each represent a particular point in time in the progress of soil research, extension, and outreach in Wisconsin. This model of historical soil scientific highlighting could serve for other U.S. states and nations.

My soil horizon has broadened. After having worked 12 years at ISRIC–World Soil Information (Wageningen, the Netherlands) and 10 years as a soil scientist in several tropical countries, I arrived in September 2011 as professor of soil science at the Department of Soil Science, University of Wisconsin–Madison, USA. As a newcomer to the state, I browsed through some of the major soils publications and dove into the rich literature on the soils of Wisconsin. This paper is a reflection of that delightful passage through books and papers.

All aspects of soil have been researched in Wisconsin, and there is a vast body of literature that goes back to the late 1800s. To list a few examples that shaped Wisconsin soil science: the agricultural physics work of F.H. King (the Benjamin Franklin of American soil science) who also wrote one of the first soil science textbooks (King, 1895), the seminal work of M.L. Jackson on silicate crystal chemistry and radioactive isotopes, the soil fertility "revolving fund" concept of A.R Whitson (Whitson and Walster, 1918), the plant mineral nutrition work of E. Truog, and the ordination concept of Hole and Hironaka (1960) that still needs to be assimilated in the soil science community. All these are renowned nationally and internationally, and there are several remarkable findings and characters in the soil science of Wisconsin, some of which have been described by Beatty (1991).

Some of the work done in Wisconsin is particularly noteworthy. Possibly somewhat biased toward my own preoccupations, I herewith highlight four specific soil science achievements for Wisconsin:

- the first soil map of an entire state in the United States in 1882;
- the development of successful soil erosion control measures in the Coon Creek basin in the 1930s;
- the seminal work on soils under forest vegetation in the 1950s; and
- the establishment of the state soil, Antigo silt loam, in 1983.

I have selected these four cases to show the breadth of the soil science discipline, and because each case represents an achievement in *research* (soil map, soils under forest), *extension* (Coon Creek), or *education and outreach* (state soil). A description of these four cases is given below.

The First Soil Map

The first soil map in the United States was made in Wisconsin by the prominent glacial geologist T.C. Chamberlin (Brevik and Hartemink, 2010). Chamberlin was the chief geologist for Wisconsin, and between 1873 and 1877, he published with several co-authors, the voluminous (3035 pages), four-volume *Geology of Wisconsin*. Chamberlin introduced the glacial stages of North America and produced an atlas that includes the first soil map of Wisconsin (Fig. 1).

The soil map shows eight soil textural groupings (Fig. 2), and the Central Sands stand out, as do the red lacustrine clays in the eastern part of the state. Chamberlin had a strongly geologic view of soils, and he considered that the character of the soil will depend on the nature of the rock, the degree of weathering, and the amount lost by leaching and gained by vegetation or capillary action from beneath (Chamberlin, 1877). He evidently recognized the difficulties in mapping soils, as he wrote: "Map of soils. There are few natural formations more difficult to map than soils. There is an almost infinite gradation of varieties between which there are no hard-and-fast lines, and it is nearly or quite impossible to represent these gradations on a map."

The impact of Chamberlin's soil map has not been assessed, but it could be that his map was an argument for the establishment of the national soil survey in 1899. After Chamberlin's map, it would take 40 years before the next reconnaissance soil map

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of the entire state was produced (Whitson, 1927). That map was later used in soil conservation planning, but also in soil fertility studies. After that, it took another 50 years until the most detailed soil map of Wisconsin was published (Hole, 1976).

These statewide maps have served numerous purposes and included evaluations for agriculture and crop yield predictions, woodland potential production, tree planting guide, wildlife, engineering, and town and country planning and recreational uses. The statewide maps forced systematic soil surveys of the entire state (county by county) and were pivotal for a deeper understanding of the soil genesis and geography in Wisconsin. They also provided a great teaching and extension tool for many generations and became a useful tool for "land lookers" (Hole, 1980). Much of the map information has been scanned, digitized, and available through the Soil Survey Geographic Database (SSURGO) since the 1990s.

Soil Erosion Control

Libraries have been written about soil erosion in the United States. Although erosion was massive in the early days of settlement and solutions were available (Dabney, 1894), there was no sense of urgency in developing soil conservation practices—one could always move west (Jacks and Whyte, 1939). That all changed in the 1930s, when a U.S. President and a soil scientist were confronted with an economic and ecological disaster—one might say an ideal Spielberg scenario. That scientist was H.H. Bennett, who with the backing of President Franklin Roosevelt, established in 1933 a New Deal agency: the Soil Erosion Service. It was succeeded by the Soil Conservation Service in 1935.

Bennett ("Big Hugh") grew up on a cotton farm in North Carolina and his soil survey work in Virginia and the paper by T.C. Chamberlin on "soil wastage" influenced his research direction. As he wrote later, the work in Virginia and Chamberlin's paper "….fixed my determination to pursue that subject to some possible point of counteraction" (Helms, 2010). And so he did, and became a prominent American soil conservationist. He wrote more than 400 technical and popular papers and in 1939 published the nearly 1000-page, classic book, *Soil Conservation*.

Fig. 1. Soil map of Wisconsin compiled by T.C. Chamberlin, 1882. The legend shows eight soil classes.

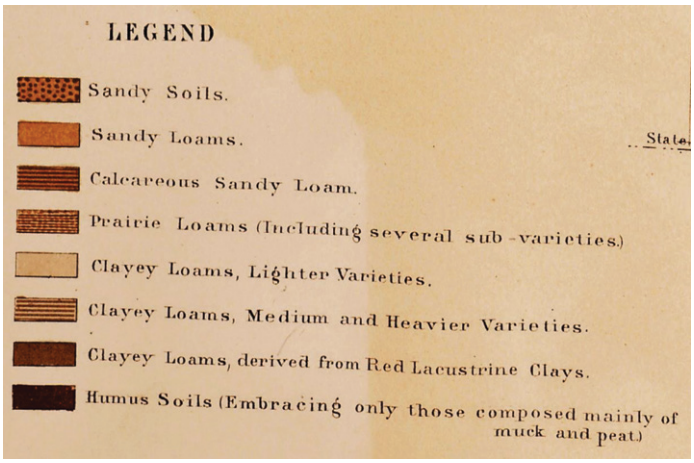

Fig. 2. Legend of the soil map of Wisconsin compiled by T.C. Chamberlin, 1882.

Bennett hatched the idea of a soil conservation district for the implementation of soil and water conservation. A national model was developed for establishing these conservation districts, called the Standard State Soil Conservation District. President Roosevelt wrote personally to all state governors and encouraged them to adopt the plan, and he made the often quoted statement, which was probably written by Bennett: "The nation that destroys its soil destroys itself."

The soil conservation district served as a mechanism for cooperative conservation action on a local scale by the users of the land. The function of the district was to develop and carry out a program of proper use for all the land. For example, the district proposed land-use readjustments and reforestation but also provided loans for land rehabilitation and purchased marginal lands or areas for wildlife. Its main activity was the installation of sound conservation practices such as strip-cropping, terracing, cover cropping, and planned rotations on all cultivated land vulnerable to erosion (Bennett, 1939). Throughout the country, nurseries were established to grow and distribute plants for the stabilization of severely eroded lands (NRCS, 2010). As Bennett (1939) wrote, "….the service enables to assist more effectively large groups of farmers who are cooperatively engaged in the prevention of *soil wastage* on a large scale."

One of the first soil conservation districts was the Coon Creek watershed in the unglaciated part (called the Driftless Area) of Wisconsin (Fig. 3). The Driftless Area has a pattern of valley bottoms, steep forested bluffs, and cropped fields. The original vegetation was oak savanna (Hole, 1976). When the first settlers came into the Driftless Area in the 1850s, wheat (*Triticum aestivum* L.) was the primary crop grown and, to lesser extent, tobacco (*Nicotiana tabacum* L.). Diseases and low wheat prices forced the settlers into dairy farming (Whitson, 1927). As the land is sloping and much of the forest was logged, there was massive soil erosion in the Driftless Area, and more than 60% of the cropped land had lost 10 to 15 cm of its topsoil (Clark, 1940). So, the establishment of a soil conservation district was highly appropriate to demonstrate to farmers soil erosion control and conservation measures, including strip-cropping, contouring, fencing woodland, and controlling gullies and stream bank erosion (Helms et al., 1996). An area of 37,000 ha was selected, straddling three counties, with direct outlets to the Mississippi River (NRCS, 2010). The work was supervised from the Upper Mississippi Valley Station at La Crosse to secure the cooperation of farmers. The Coon Creek soil conservation district was designated Project Number 1 in November 1934 (Helms, 2010).

Coon Creek fulfilled Bennett's concept of a comprehensive approach to soil conservation and became an icon of soil conservation in the United States. Among others, the scenic landscape of the Coon Creek with its stripped cropping and grass waterways was featured in *National Geographic*. The impact was large, and the district became a showcase to other farmers in the region.

Fig. 3. (Upper) Gully erosion started in 1915 and photographed in the 1930s near Hixton, Jackson County; (middle) eroded pasture near Holmen, La Crosse county; (lower) H.H. Bennett, his wife, and regional conservator A.E. McClymonds on the Frank Milsna farm in Vervon County, which is on the Coon Creek Demonstration Project. Photos from Clark (1940) and NRCS (2010).

It showed the benefits of soil conservation and what concerted actions could make possible. According to Trimble and Lund (1982), average soil erosion rates in the 1930s were estimated to be about 34 Mg ha^{-1} yr^{-1} but had decreased to about 8 Mg ha^{-1} yr^{-1} in 1975. The reduction in erosion mainly resulted from improve-

ments in land management and to a lesser degree by changes in land use. The total area under cropping had not changed much between the 1930s and 1975, but soil conservation management was greatly improved. The practice of contour strip-cropping has spread from the Coon Creek basin to other areas (Trimble and Lund, 1982).

Soils under Forests

Humans have lived in Wisconsin since the last ice age ended. When the first French settlers arrived in 1634, most of the state was still covered with forest (Campbell, 1906). At the beginning of the 20th century most of the natural forest had been logged (Whitson, 1927). Soil science as a subject for study did not receive much attention in the early years of settlement. Research on soils in forests was well developed in Germany in the mid-1900s, and German scientists brought the study of soils into the forestry discipline. Studies were conducted on tree–soil interactions and the role of soils in increasing wood production. Also in the USSR, soils under forest received research attention (Tiurin, 1930). In the United States some forestry schools' students took classes in soils, but these were usually given in the agricultural departments. This lasted until the 1940s, after which several national institutions took a leading role in soils research in the USA. These were Yale, Cornell, Penn State, Duke, and the University of Wisconsin (Gessel and Harrison, 1999). The person who brought soil research in forests to the forefront in Wisconsin was S.A. Wilde.

Sergei Alexander Wilde (1898–1981) was born in 1898 near Moscow, Russia, where he was introduced early to the boreal forest ecosystems he came to love. He arrived at Ellis Island in May 1929 and joined the Soils Department of the University of Wisconsin in 1934. He aimed to interpret forest soils as carriers of definite floristic associations, as media for the growth of nursery stock or forest plantations, and as dynamic systems that react to different forms of silvicultural practices. His primary aim was to enhance the production of wood without depleting the soil fertility or contaminating the environment. Wilde authored one of the classic and most widely used reference books on forest soils (Wilde, 1946). His work on the site-soil requirements for successful establishment and development of planted species is acknowledged as a classic research effort (Gessel and Harrison, 1999). Wilde's investigations had an enormous impact on the forest economy of the state. Practicing foresters in Wisconsin, managing private and public lands, state and federal forest services, private nurseries, the pulp and paper industry, and owners of Wisconsin's private woodlots are better off today because of his insight and approach to sound forest management (Wilde et al., 1949). His work in the field of forest soils research included important studies on soils, woody-plant nutrition, tree–mycorrhiza relationships, and reforestation.

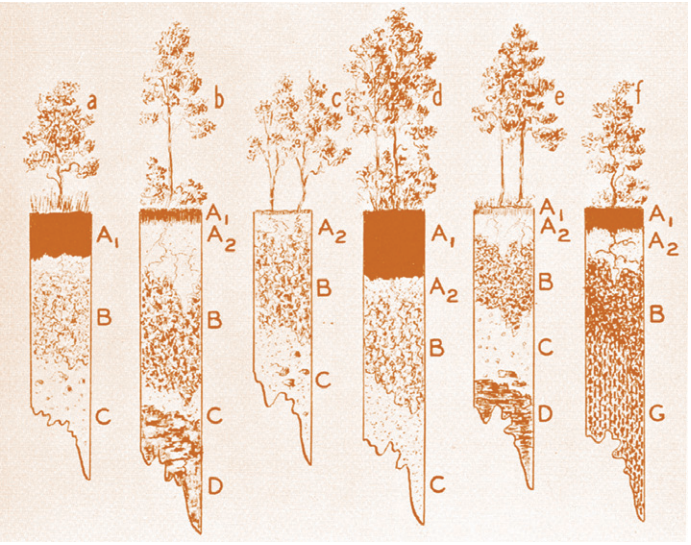

Fig. 4. Schematic presentation of typical soil profiles under prairie forest (from Wilde et al., 1949). These diagrams were drawn by S.A. Wilde and show the effects of the soil on the trees and the effect of the trees on the soil.

Wilde was not only able to bring some soil science into forestry, he also brought forestry and vegetation knowledge back into soil science. His book contains numerous drawings of soil profiles and landscapes in which he systematically unraveled the effect of the tree on the soil and the effect of the soil on the tree (Fig. 4).

The Wisconsin State Soil

Since the official start of the soil survey program in the United States, many thousands of soil series have been mapped and named. The soil series is the most homogenous category, and as a class it is a group of soils or polypedons that have horizons similar in arrangement and in differentiating characteristics (Soil Survey Division Staff, 1993). The series name is typically taken from a town, village, or stream near the area where the soil was first defined. In the 1970s, some soil scientists started to advocate the concept of state soils. They drew a parallel that many states already have natural state symbols like, for example, a bird, flower, tree, or rock.

Professor Francis Hole from the University of Wisconsin–Madison proposed the state soil in 1977 (Hole, 1977). Nebraska was the first to have a state soil (Holdredge silt loam) in 1979, followed by Wisconsin in 1983, and Vermont in 1985. By 1991, 10 states had a state soil (Quandt and Watts, 1995), and presently each state has selected a state soil, but only 20 have been legislatively established. These official state soils share the same level of distinction as official state flowers and birds.

The establishment of the state soil of Wisconsin was a long and tedious process, and it took Hole, with the help of several key legislators, 7 years to accomplish his aim (Devitt, 1988). That means he began thinking about the state soil in 1976. Francis D.

Hole (1913–2002) was a geography and soil science professor at University of Wisconsin–Madison from 1946 until 1983. He co-wrote a standard textbook, *Soil Genesis and Classification*, and a seminal book on the soils of Wisconsin in 1976. He retired in June 1983 but remained active in education and lectured to any interested audience, from preschoolers to academics to retirees, about humanity's stake in the soil. Hole was one of University of Wisconsin–Madison's most popular teachers, and a sought-after guest lecturer. He spent a lifetime teaching folks "not to treat soil like dirt" and was an outstanding soil scientist and a true University of Wisconsin–Madison scholar.

The original correspondence about the Wisconsin state soil is at the Department of Soil Science at University of Wisconsin–Madison and Hole wrote an extensive summary, of which the following sections were taken:

> At 10 a.m. on Friday morning, September 9, 1983, Anthony Earl, Governor of Wisconsin walked from his office into the crowded, stately conference chamber and sat down at a polished table to sign Senate Bill 89 designating the Antigo silt loam as the State Soil. With a twinkle in his eye he began: "I suppose that this is a dirty job that someone has to do! Joking aside, I am glad to see that a grass-roots movement has brought about this recognition of our soil resource." Onlookers included Cliffton A. Maquire, State Conservationist from the U.S. Soil Conservation Service, Senator Fred Risser, the bill's main sponsor, other legislators, citizens, newspaper reporters, radio and television people, university students and a dozen school children who had followed the bill through the whole process. I was asked to lead the group in singing the Antigo silt loam song.... The political process to name a State Soil began in the early spring of 1982 when Republican Senator Clifford Krueger, from North Central Wisconsin, where 150,000 acres of the Antigo silt loam support dairy farming, potato production and forestry in twelve counties, sent a message to me by telephone: "The Senator read the article in the current Milwaukee Journal about the campaign for a State Soil, and he wishes to sponsor a bill to bring that about. Please send us information about the Antigo silt loam so that lawyers can prepare correct wording." That bill died because it originated so late in session that there was not time for required hearings. At the beginning of the next session, in the autumn of 1982, Senate Bill 89 and Assembly Bill 60, both designating the Antigo silt loam as the State Soil, were introduced. It was Democrat Fred Risser (of Madison), President of the Senate, who acted first, and it was his bill that was on the Governor's desk for signature on September ninth. A senate committee held a hearing about it on March 15 and the bill passed the Senate on April 19. The Assembly held a hearing on May 10 and the bill passed the Assembly on June 1. The hearings were well attended by school children as well as adults. The two committees related well to the children, explaining to them the procedure as it went along. A twelve-minute puppet show was presented in which conversations and other interactions between Bucky Badger (the state animal), Terra Loam (a character representing the soil) and Erosion (a soil-eating monster) made it clear that the Antigo silt loam should be the State Soil. Sue Bridson, Nancy Dott and other University Arboretum and 4-H naturalists served as puppeteers. Five-year-old Anna Sugden-Newberry led the singing of the Antigo silt loam song, on one occasion. Some attenders wore Antigo silt loam T-shirts, with a logo on the front showing the soil profile and scenes from a dairy farm, a potato field and a forest, and with words to the song on the back. (Hole, unpublished report)

This was a special moment for Hole as it saw the fruitful ending of 7 years of political work. In the same note he also lists the opposition to the Antigo state soil:

> Opposition at the hearings was moderate and had three main themes. One was that the bill was frivolous and unworthy to claim the time of busy legislators in a year of unprecedented deficit. Talk of other bills to establish a state dog, a state drink and a state fossil did not help matters. Some lawmakers protested what seemed to them to be a Wisconsin symbol craze. A second objection was that the Antigo silt loam was not representative of districts from which most lawmakers came. "The state tree is the sugar maple," declared one legislator, "and it is all over the state. The State Soil should be too, and the Antigo silt loam does not qualify." The fact that potatoes from Antigo soil are sold all over the state did not seem to compensate. A farmer-senator from southwestern Wisconsin spoke up for the Dubuque silt loam, but was over-ruled. "It is an insult to the whole agricultural community," he said, "that a northern glacial soil that won't even sprout jack pine is being proposed for State Soil." The Kewaunee silt loam, with red clayey subsoil, was tauted as best candidate by a farmer-representative from eastern Wisconsin, who enumerated its virtues: agriculturally productive, excellent material for sealing sanitary landfills, good material for making bricks, and carrying a name (Kewaunee) that school children can be trained to spell more easily than Antigo. A third objection was that the Antigo silt loam is not the most productive soil in the state. The Suamico muck outstrips the Antigo in output of tons of carrots, onions, mint, and head lettuce per acre. One legislator proposed that there be six State Soils, to be rotated on an annual basis into first place. When politicians challenged the workability of the State Soil concept on the basis of the supposed impossibility on making a picture of a soil, supporters displayed the logo on their T-shirts, to good effect....
>
> The dominantly positive thrust of the entire campaign for a state soil was clearly powered by people's love of the soil, appreciation of its role in maintaining terrestrial life,

and genuine concern for conservation of the soil. Communications from urbanites as well as from rural folk were overwhelmingly enthusiastic. "If we didn't have soil, what would we walk on?" asked a boy at a hearing.

The educational process that led to the climax in September began in 1976, 3 years before the Nebraska Legislature designated the Holdrege silt loam as the Nebraska state soil. In 1976 the Environmental Decade, a watch-dog organization, published an interview with me concerning my understanding of the need for a symbol of the soil resource. Newspapers picked up the item with a sense of humor mixed with a real appreciation for our soils. In 1979 the Wisconsin Association of Soil and Water Conservation Districts passed a resolution with the same purpose that Senate Bill 89 had 3 years later. I continued to get invitations from schools and clubs to make presentations, which I did with the help of my violin, songs, poems and color slides. Newspapers carried reports of these events. A few journalists joked about "dirt" and proposed unsavory materials as more suitable than Antigo silt loam, such as dirty air over Milwaukee and concrete. But the tone of most articles was good. As the political process got well under way I was asked to appear on television and radio with my violin, and Senator Risser was quoted from coast to coast as saying that he was quite serious about his bill. He wore an Antigo silt loam T-shirt to the signing ceremony on September 9, as did many others. "The Antigo soil is not the world's richest soils, but it isn't the world's poorest either. It is unique… found only in Wisconsin," said the senator.

One technical problem arose which proved to be of little interest to the public. It was that the soil near the city of Antigo in northeastern Wisconsin was found not to fit the central concept of the soil series. It seems likely that bodies of the soil in that area will be considered as variations ("taxadjuncts") of the Antigo silt loam. The campaign for a Wisconsin state soil has been a success. A picture of it will appear in the Blue Book, the official state governmental annual volume, along with traditional sketches of the badger, the robin, the sugar maple tree and other state symbols. But the educational campaign to offer pupils and citizens ongoing opportunities to increase and express their appreciation of the soil resource still has far to go. The positive response of the public thus far indicates that people welcome opportunities to be acquainted with the soils of their landscapes. The Antigo silt loam song that I contributed to the campaign consists of a verse and a tune. The tune is an adaptation from a phrase of violin music by J.S. Bach. (Hole, unpublished report)

Besides the Wisconsin state soil (Fig. 5), another significant contribution of Hole was the establishment of *Soil Survey Horizons* (Brevik, 2012).

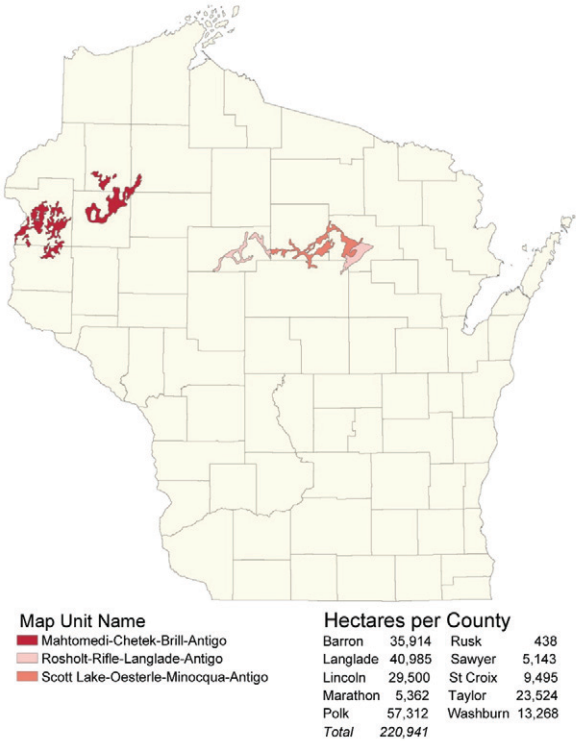

Fig. 5. (Left) The distribution of Antigo soil loam in the state of Wisconsin. (Right) Francis Hole.

Discussion and Conclusions

The impact of soil science on the welfare of people, the national economy, and the management of our natural resources has been poorly documented. In part that is the case because the results from our research are often only indirectly used in policy and decision making, and in part it is because our results are not so well communicated (Greenland, 1991). Another possible reason is that we have been a bit modest, down-to-earth, and inward-looking. Noble as that is, it would not hurt if the soil science discipline also proclaims its achievements and scientific successes.

This paper presented four noteworthy soil science achievements in the state of Wisconsin. These four cases merely serve as a recollection of fascinating facts and noteworthy soil science achievements in Wisconsin. They also serve as an example of achievements in research (soil map, soils under forest), extension (Coon Creek), and education and outreach (state soil). It is these three pillars—research, extension, education—that have made soil science so successful in Wisconsin, and in nearly all other parts of the world.

In the 1970s, the first idea for a state soil was hatched. It has been successful, and now all states have their state soil. Here I propose that each state makes a list of its grand soil science achievements. The main purpose is to look back on research activity and speculate on its impact and how it has influenced our current thinking and impacts the future. In doing that, we may unearth some hidden treasures of our discipline and celebrate some of its successes.

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