We will be feeding 2 billion more people by 2050. We need gene editing to do it.
By Peter Beetham, Ph.D.

English scholar Thomas Malthus made his first predictions about population economics and resources in 1798. More than two centuries later, there have been many projections that the world population will eventually outstrip agricultural production.

The consequence? Mass starvation.

Mercifully, agricultural production has kept pace and mooted those predictions over the last 200 years. This is in part because vast stretches of wilderness have been converted to cropland. It's also in part because breakthroughs in farm practices, agronomy and the technology of plant breeding have increased the amount of food an acre of land can produce.

But we can no longer count on new lands to feed the world. Our population continues to grow by 81 million a year. Total arable land has been flat for decades, and since 1961, the amount of arable land per person has been nearly cut in half. To feed the world, we must get more out of what we have left — or perhaps even less than that, with climate change and land degradation exacting a toll on the productivity of existing agricultural lands.

If we fail to meet this challenge, we may discover that Malthus' fears were not defused. Just delayed.

Given these trends, only a new technological breakthrough will enable the world to meet the food security challenge. Fortunately, one is at hand and actually producing results in the field: gene editing. By mimicking the way plants adapt in nature, it holds the promise of powering a second Green Revolution, improving agricultural yields and helping enable farmers to deal with the rising problems of drought, flooding and the salinization of farmlands. Expanding the reach of this technology will also take some pressure off of wildlands, and help restore biodiversity to crops and soils.

So, what is gene editing?

Gene editing has become a complicated, mixed-bag term. The phrase describes the act of altering a gene, which is exactly what nature has done for billions of years in natural selection. Without it, we would still be single cells in a salty soup. Natural gene editing occurs randomly, resulting from mutations caused by such impacts as solar radiation. These natural experiments proceed through trial and error; those organisms with genetic changes that better fit the circumstances of a particular time and place will thrive, while others fade.

The difference between precision gene editing and natural selection is that precision gene editing is not random. Scientists first determine the precise functional pathways through which a plant resists a blight, for instance, and then edit the genome to replicate that pathway.

For context, it's crucial to understand the difference between precision gene editing and transgenic GMO approaches. For GMO's, a trait might be imported from another plant, or by tweaking the genome in introducing foreign genetic material (that's what 'transgenic' means). By contrast, in some forms of gene editing, no foreign DNA is introduced; scientists only operate within the plant itself. This approach carries with it dramatic advantages in terms of precision, speed and the breadth of applications, and none of the baggage of transgenic technologies.

Biologist Detlef Weigel, director at the Max Planck Institute for Development Biology in Tübingen, agrees with this assessment in the German publication Der Spiegel: "Modern genome editing methods that change individual genes are much more targeted. Random mutations also play a major role in breeding. Afterwards, it is no longer possible to tell from the plants themselves whether they have been genetically modified or not."

Multiple issues, a single solution

To illustrate the role gene editing will play in feeding the next billion people, let's look at one global problem: access to fresh water. While agriculture has kept pace with growing human numbers, the expansion of farmlands has come at a cost to wildlands and genetic diversity. We depend on functioning ecosystems to maintain the overall stability of the biosphere, and so further increases in agricultural production must be made with ecosystem stability in mind.

Today, some 40% of the world's population lives in a water-scarce area. Agricultural demands on fresh water (70% of total withdrawals) increasingly come at the expense of natural ecosystems. As climate change shifts rainfall patterns, it will become increasingly more important to breed crops that can cope with such changes.

Over millions of years, various plants have already evolved defenses to deal with environmental changes, such as drought, heat stress, diseases and saline soils. Evolution has optimized organisms using innate gene editing machinery to deal with these types of challenges in the most efficient manner. The key word here is "efficient:" plants have adapted in such a way as to use the same machinery to deal with various challenges. For example, plants respond the same way to heat stress as they do to water stress, but this genetic efficiency extends even further. Plants rely on this same genetic response to deal with stresses caused by plant disease.

This gift from natural evolution means that gene editing can solve several problems with one solution. Working at the level of the plant's genes, if scientists can understand the various genetic pathways one plant has used to resist a plant blight, they can edit genes in another plant to bolster that plant's defenses. Even better, because nature has tended to bundle various challenges, if a plant is resistant to a blight such as Phytophthora or Fusarium, it can also increase the plant's ability to withstand drought.

<u>Extending nature's toolbox</u>

Consider a water-related issue has been approaching crisis levels: the salinization of soils that has left huge swaths of farmland virtually unusable. Both dryland farming in arid areas and overuse of irrigation can damage soil over time, as evaporation increases salt content to toxic levels. The figures are staggering – nearly 1 billion hectares (or 1/3 of all potential cultivated land) has been damaged by salt, and 60 million hectares (or 24% of all irrigated land) has similarly lost productivity due to salinization.

Using nature's toolbox, we can edit genes to help plants adapt to these increasingly saline conditions. For example, plants on marginal lands have developed ways of transporting toxins such as metals out of cells where they can do damage and into what might be described as "holding cells." If a plant can move toxic metals and render them harmless, it can also move sodium out of cells and segregate it where it can do less damage. Through gene editing, we can enhance a plant's ability to develop salt tolerance. It's true that over time, nature could do that, too. But, with millions of hectares being lost to salinization each year, we don't have that time.

Given constraints on agricultural land and access to water, feeding the next billion people will require getting more out of the land already under plough without further damaging the ecosystems we depend on. Reclaiming farmland damaged by salt and developing crops tolerant of salt is one way to accomplish this.

But the applications extend far beyond that. Gene editing can be used to help solve some of our largest impending agricultural crises, from developing crops that are resistant to disease to those that are more likely to withstand drought. It can be used to prevent the overuse of pesticides and fungicides – a mounting issue, as the antifungal-resistant and deadly *Candida auris* has shown us. And it can even be used to create a non-allergenic form of the peanut – something that will reassure millions of mothers that it's now safe to give their kids a PB and J sandwich.

Gene editing can achieve all these goals. And even more.