# Woody Agriculture - On the Road to a New Paradigm

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*This is a guest post by Philip A. Rutter, B. L. Rutter-Daywater, and S. J. Wiegrefe. Phil Rutter is the Founding President of The American Chestnut Foundation; trained in ecology and evolution, he has been working in SE Minnesota for 35 years on domesticating several woody plant genera for commodity agriculture-style food production. I know Phil personally and believe in woody agriculture as a partial response to the energy/environmental constraints we face, (and just planted 300 hazelnut seedlings this spring).*

In any attempt to comprehend a puzzle, or choose a new path forward, the first requirement is to see and comprehend each of the possibilities. We wish to bring to the attention of the energy community a potential food and biomass energy paradigm, previously unknown, to your considerations.

Our current agricultural paradigm choices include either "industrial" agriculture; large scale with extensive fossil fuel inputs, or the "organic" routes, usually deemed insufficiently productive by professional agronomists. Claims that agriculture can yield significant energy, while also producing the necessary food for the world, are a matter of rancorous dispute.

The current article will present a 3rd paradigm, depending on newly domesticated woody plants for primary food production, equal to industrial agriculture. These crops capture far more solar input than row-crops can; and always also produce wood; some of which will always be available for energy purposes. This work has been quietly underway for 35 years; farmers are now growing the crops. We here present basics on how the energetics work, practices, outputs, and the state of the art.

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Most Oil Drum readers will be familiar with the Land Institute's work and hopes for a perennial agriculture based on future domestication of wild perennial prairie grasses. The Land Institute is a non-profit, and one of its major products is publications.

Badgersett Research Corporation (BRC) has been working over the same time period, but with a very different goal; a perennial agriculture; but based on woody plants rather than grasses. Very few are aware of this work; partly because we are a C corporation, i.e. for-profit, and publicity priorities are quite different. Why did we choose the business pathway instead of the non-profit? If our work is to have impact on the real world- it must make economic sense; and demonstrate that.

To start with the bottom line; after 30 some years of work, in 2010 the official position of The Land Institute remains that "we estimate that commercially viable perennial grain crops could be available within 20 years." No farmers are growing any, anywhere. In the same time frame, over 500 growers across North America have made experimental plantings of Badgersett neohybrid hazelnuts, with approximately 100 of them now actually planting for crop production; last year saw the first actual machine harvest, and five universities have launched their own independent hybrid hazelnut research programs (U MN, U WI, UNL, Rutgers, OR State); all following our lead.

**The reason this should be of interest to the energy community** is that woody plants produce biomass, as well as seed (oil and protein). It has always been an intrinsic part of our design that various wood (and oil) components of the system would be produced as an energy crop. We are now struggling to keep up with the biomass production on our primary farms in Minnesota and Illinois. For those with concerns beyond the energy arena, we wish to point out that the woody food crops we are developing are specifically designed to be both resilient and versatile, aspects so far not included in the various proposed "dedicated" biomass energy crops.

It is of course impossible to entirely present and delineate an entire paradigm in the course of one blog post. Make no mistake, we're talking about a full paradigm shift; potentially achieving primary world food production from woody crop plants. We will however attempt to present the skeleton components and rationales, and high points, with references to additional resources. Covered are Energetics; Genetics; Products; Practices; Progress; and the Future. Be warned that the links provided are generally to large full discussions, not brief notes.

**We call it "Woody Agriculture**", tightly defined as: "The intensive production of agricultural staple commodities from highly domesticated woody perennial plants."

We breed 3 genera of woody plants, hazelnuts (*Corylus*), chestnuts (*Castanea*), and hickory-pecan (*Carya*), for crops with wide adaptation and multiple uses, each with both food and biomass components. Both bush and tree forms are under development.

What we work on is distinct from the multiple versions of "Agroforestry", which typically means growing timber with food crops, but no significant food from the trees themselves; and from "Tree crops", the traditional practices described by J.Russell Smith in 1929, which do not include the potential for crop improvement using modern genetics. Agroecology and Permaculture are additional embodiments of progressive alternative agriculture; mainstream agronomists tend to feel both may deliver more ideologies than technologies, and so far can demonstrate few impacts on global problems. None of these alternatives have proven attractive to large scale farmers; and it is specifically large scale agriculture that has the most serious environmental impacts.

The many potential benefits of a perennial agriculture have long been recognized. The senior author first presented our concepts at the "2nd North American Conference On Preparing For Climate Change", in 1988; with additional aspects discussed at the climate conference in Cairo, Egypt, in 1989. A more recent and fairly linear introduction is on our website. An earlier informal expatiation can be found here, and of course The Land Institute has frequently expounded on the subject.

For students of energy systems, a major question in proposed perennial agriculture has always been how to dissect inputs and possible gains, and how to compare such theoretical systems with those in place. Stating our bottom line first; long term inputs are dramatically smaller than for standard agriculture, and potential solar energy capture is very much greater; in the range of 3X more than single crop maize.

Why don't we already get our crops from trees, if this is such a good idea? That is the quintessential question faced by every innovator since time began; and it is a question known to rarely have merit. Most of our technologies exist as they are because our grandparents inherited them from their own grandparents. That is most especially true in agriculture. The full answer will make a tome, some day, but start here: there are several assumptions widely made about trees, that turn out not to be true.

A very topical advantage: as we write this, the US is in the grip of a broad and severe drought, already affecting crop prices and raising great concern. Our neohybrid hazels, growing under the same conditions which have destroyed neighboring corn fields, are nearly unaffected- except they are ripening their seed crop ahead of schedule. Experience in a similar drought in 1988 showed they could bear the crop, and also bear their crop in the next year.

Woody crops are also more tolerant than row crops to the other end of the weather spectrum; flood. Flood water that covers young annual plants will generally kill them; but woody plants, with their tops above water, are essentially unaffected.

As we proceed into global climate change, this broader tolerance of environmental variation will prove increasingly desirable.

One additional energy related advantage: woody agriculture can produce food; on the same scale as modern agriculture. But because of the 3X energy capture aspect the same crop can simultaneously produce a biomass fuel component. In the case of hazelnuts, our top recorded experimental yields, based on multiple single-bush data, indicates that food production exceeding soybean averages is attainable, with the nutshell component of the crop available for fuel, annually.


***Figure 1***

Dry neohybrid hazelnut shell is dense, with an energy content measured at 8,800 BTU/lb, at 1.8% ash. The wood component of the crop is harvested on a rotating basis, approximately once every 8-10 years. The entire energy picture for these crops is much more complex, and very importantly- flexible, within and between years, always with the potential to retain the food component.

The conflict between producing food and producing biofuels already has been a matter of heated debate, which will only grow more acute in the future.

For those with the interest, an hour-long video lecture is available on YouTube; the recorded introductory presentation from our annual 2 day Short Course. Be forewarned, this is an unhurried format, and starts out slow by internet standards; but the pace does pick up, and it is comprehensive.

**ENERGETICS**


***Figure 2***

Because woody perennial plants use energy stored from the previous year's photosynthesis, they are able to deploy a full functional, deeply 3 dimensional solar collection array very rapidly, as soon as local average temperatures make physiological processes efficient. Annual row crops, of course, must build new collection capabilities out of current energy capture; and while perennial grasses also used stored energy to deploy collectors, they cannot achieve nearly the same depth or complexity.

One limit for any agricultural system must be; how much sunlight can be captured; assuming water and nutrients are not limiting? This question was not asked, during the evolution of world annual crops; they were developed in antiquity, for quite unrelated reasons.

In attempting to design a system from scratch, it is wise to seek natural limits, where they may be visible. In the case of agriculture; where does nature achieve its greatest efficiency? Vast amounts of academic effort have been expended on the measurement of "primary productivity". The difficulties to making valid comparisons between ecosystems – remains equally vast. In searching for an alternative metric, we found one that we believe provides excellent, reproducible measurements of "photosynthetic potential". That measure is simply the total amount of chlorophyll currently present in the system being studied. We are aware that not all chlorophyll is "equal" in terms of actual productivity, the number of confounding details being large; but in general plants do not maintain chlorophyll that is not in use at all; individual plant cells typically make, and resorb, chloroplasts depending on current needs. If it is present; the plants are making some use of it.

In their seminal article "Comparative Chlorophyll and Energy Studies of Prairie, Savannah, Oakwood and Maize Ecosystems." Ecology, Vol 48 #4; pp 515-524 1967; JD Ovington and DB Lawrence took measurements over the course of the year in those four ecosystems. Their findings are very telling:

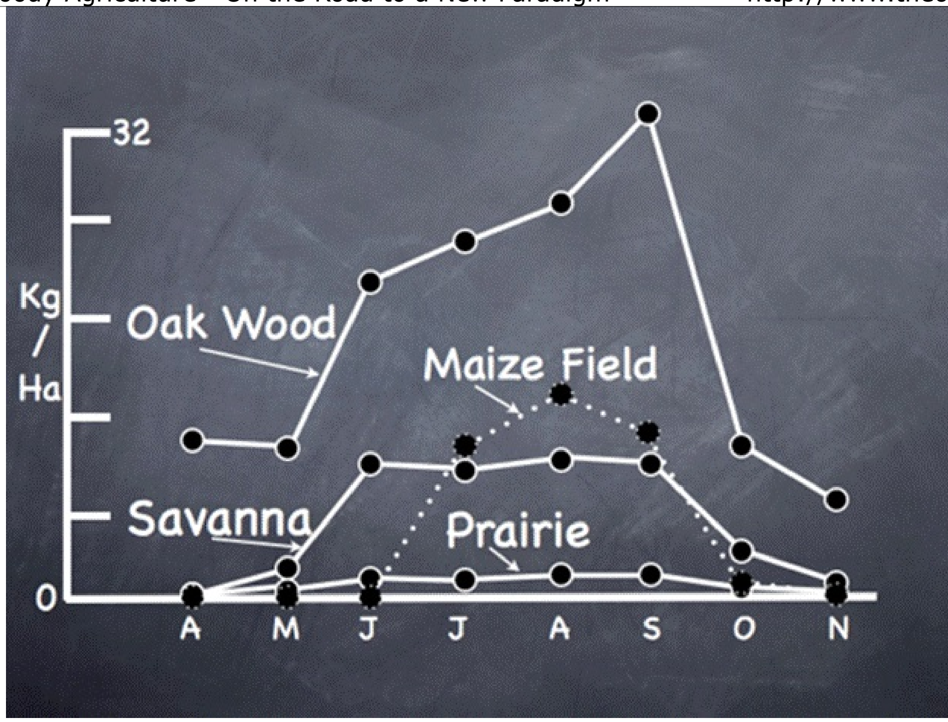


***Figure 3***

In terms of ecosystem potential energy capture, the forest dramatically outstrips both agriculture and grassland systems. The "savanna" is mixed tree and grass. The prairie is the least active of the natural systems measured; most natural prairies exist as such because of a climatic lack of water. Notice that in April, the oak woodland starts out with more chlorophyll present than ever exists in the grasslands. We can confirm that measurement is correct, and we find the chlorophyll in surprising places, doing work we end up harvesting.

Another useful hint about where to look for productivity should come from agricultural statistics. FAOSTAT is a stunning goldmine of global data, accessible to all; but making broad comparisons between crops regarding "food" turns out to be exceedingly complex. Protein content of cassava, for example, is hard to compare to the carbohydrates values in wheat. Edible oils, however, are more directly reported, allowing us to generate the following graphic, once conflicting measures were translated. We reiterate; the numbers for hazel are calculated from research; *not* measures of actual field production.

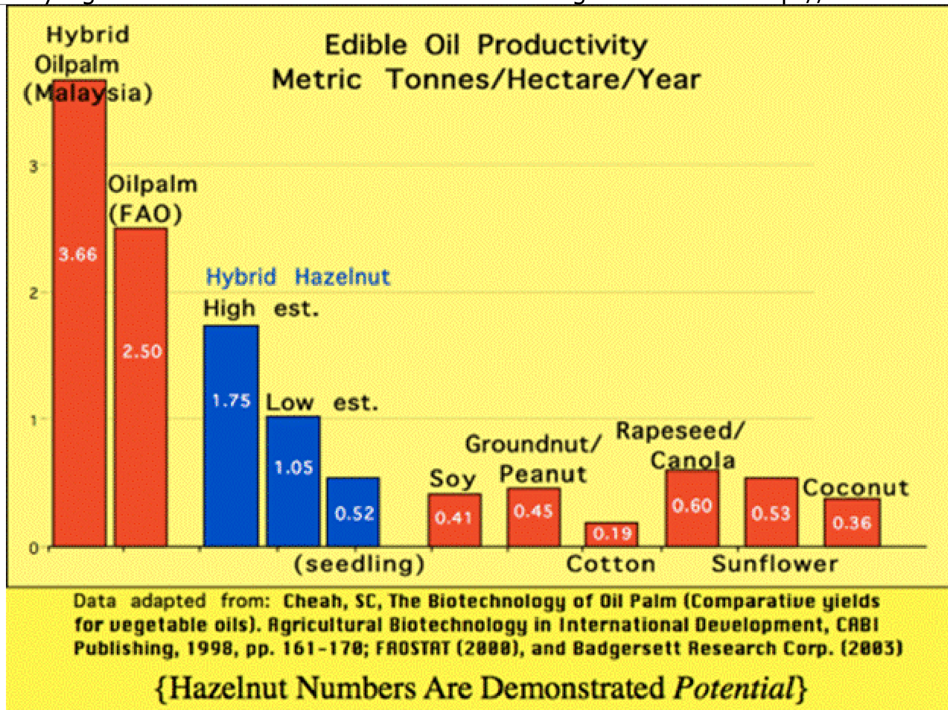


***Figure 4:*** *Note that the hybrid oil palms in Malaysia are in fact crosses between different species of palms, like our neohybrids; and in terms of oil alone they out-produce soybeans, so widely touted as the pinnacle of modern agricultural science, by nearly an order of magnitude. The low blue bar is our estimate of current neohybrid hazel genetics, which we know to be still well short of eventual potential.*

EROEI calculations for these crops are simply not yet available; but in all equations, the numbers for "tillage" expenses can be deleted from any woody perennial crop.

**GENETICS**

We regret having to coin the word "neohybrid"; neologisms are always irritating, but it is necessary. Modern agriculture is dominated with "hybrid" crops, and both scientists and farmers believe they understand what that means. "Species hybrids" is technically correct, but utterly inadequate to describe our gene pools, and with no real meaning accessible to farmers.

Our crops are being created using a genetic technique absolutely unrelated to the farmers' definitions of "hybrid". Specifically, we utilize a natural process known to evolutionists as a "hybrid swarm." Hybrid swarms are documented occurring in nature across all examined organisms, plant and animal. In our opinion, it may prove to be one of the most common sources of speciation. In some cases, natural hybrid swarms are so productive of new genotypes adapted in different directions that they have been called "species swarms" in an attempt to convey the complexity generated.

Modern agricultural hybrids are created by extreme inbreeding, within one species. When two such inbreds are crossed, seedlings are highly heterozygous, generating the hoped for "hybrid vigor", and also a population where all individuals are virtually genetically identical to one another; i.e. with extraordinarily low genetic diversity.

Neohybrids are as far on the other end of the scale of individual genetic diversity as it is possible to get. In fact, our populations of artificially created hybrid swarms are generating genetic diversity that is not possible to attain through standard breeding. Rather than working with a gene pool derived from one species, we have individuals containing genes from as many as 4 different species; in an unprecedented wealth of combinations- which are all nevertheless from related organisms. All the genes in the hazel swarm- are hazel genes; no genetic engineering is used.

Our hybrid swarms may be described as:

•NeoHybrid Hazelnuts = (*Corylus avellana* X *C. americana* X *C. cornuta*)[5]
•NeoHybrid Chestnuts= (*Castanea mollissima* X *C. dentata* X *C. sativa* X *C. crenata*)[4]
•NeoHybrid Hickory/Pecan = (*Carya illinoiensis* X *C. ovata* X *C. cordiformis*)[3]

By no means are all the resulting individual plants either "vigorous" or even desirable; a great many must be rejected. Computerized record keeping on multiple years of performance is critical. However, many such hybrids do show traits valuable for purposes of domestication, e.g. increased seed production beyond what can be found in wild populations. We call this process Accelerated Guided Evolution (AGE).


***Figure 5***

Precise details of the inner genomic workings of these hybrids is far beyond the scope of this article. The "proof of principle" for AGE breeding lies in the fact that in 30 years; in 3 different crop genera; we have demonstrated dramatic statistical advances in: climate adaptation, disease resistance (our gene pools are fully tolerant of chestnut blight and Eastern filbert blight), annual crop bearing, heavier crop bearing, and shortened generation times. At the extreme end of the heavy crop spectrum, we have generated hybrids that can kill themselves by "overbearing". Generation time has been shortened to the theoretical maximum for hazels and chestnuts; some breeding lines regularly produce individuals which commence flowering a few weeks after the seed germinates. That extreme precocity will become more useful as we accumulate genetic "markers", so that in the future crosses can be made "blind", with predictable results.

**PRODUCTS**

From the outset, our crops have been developed to produce multiple products. One of most dangerous practices of modern agriculture is the establishment of the special purpose "cash crop";

the crop with no actual local utility. Cotton is an excellent case in point. Under ideal conditions, the grower can sell the crop and make a cash income with which other needs can then be met; however "ideal conditions", including anything from details of international trade far beyond farmer influence to drought, may collapse, leaving the farmer with a product of no value. Farmer deaths are widely documented, and even more widely claimed.

"Resilience" is the current buzzword for futurists. A major reason soybeans have been so profitable for farmers is that they have an exceptional number of alternative uses. As a basic industrial feedstock, the neohybrid hazelnuts can easily equal soybeans; but in addition produces nutshell and wood products, both with multiple product potentials.

A very abbreviated summary:

•Non-perishable commodity foods (dry nuts are less perishable than grains.)
•Protein – avg 10%; nutritionally complete
•Oil
–Hazel kernel is 60% oil; the chemical twin of olive oil
–Hickory/pecan is 70% oil
–Biodiesel demonstrated
•Carbohydrate – chestnut 50%, comparable to maize
•High density nutshell (pelletize/gasify/burn, bioplastics feedstock, chemical extractives)
•Hardwood biomass (fuel, paper, OSB, lumber, etc.)

From the farmer's standpoint, every year a crop is produced with relatively standard, simple, harvest requirements, but multiple and complex markets available. In the event one specific market becomes unavailable, another market can likely absorb the production. In the event of complete market collapse- the farmer can eat the food produced, or feed it to livestock, or use the fuel personally or in the local community. The farmer- survives any market collapse.

**PRACTICES**

**Tillage**: we use none, following the year of establishment; current expectation is that these crops will be planted only once every 50-100 years. Actual lifetime of the trees involved is much longer; we expect field renovation may be desirable to install advanced genetics. While tillage is used in many existing orchard/vineyard crops, our design preference is for a grass/legume intercrop, managed in varying fashion, utilized for hay or animal pasture.

While these ultimate "no-till" crops are frequently cited by others as being suitable for "marginal" crop lands, we do not make that recommendation. Marginal soils are at best steep; making machine harvest and other management more expensive, and at worst dry with poor soils- meaning crop yields will also be poor. Woody crops are expensive to establish compared to annual crops; good returns are critical. The woody crops may eventually perform better than tilled crops on such soils, but marginal land is not a pathway to seriously improved food or biomass production.

**Pest management**: we have found that "ecosystem pest management", the provision of diverse habitat for the maintenance of insect predators/diseases – works. We currently use no pesticides of any kind, and do not foresee a need. Besides habitat maintenance, genetic improvement of crop adaptations to pests is perpetual.

**Fertilizer**: yes, of course. The woody crops must establish large root systems and above-ground wood in order to function. Wild trees take decades to achieve maturity, partly because they must accumulate basic nutritional components in the very small increments normally available to unmanaged environments; a bird dropping here, nutrients from a dropped branch there. Establishing food producing crop plants in the human time frame requires considerable fertilizer inputs.

Our current belief is that providing fertilizer on the same order as that used for maize will be necessary for the first 10 years; following that, the necessary inputs decrease. Some ongoing inputs will prove necessary; to the extent nutrients are removed in harvested crops, they will inevitably have to be replaced.

Applied fertilizer does not escape into aquifers or drainages. The first infrastructure these woody crops build is a huge, permanent root system; according to actual experiment a 6 year old hazel field captures 100% of applied fertilizer.

**Machine harvest** is now a reality for the neohybrid hazelnuts. Machine harvest of chestnuts is done in several places around the globe, although the #1 producer, China, harvests by hand. We expect pecan harvesting machinery to be easily adaptable to the neohybrid hickory-pecans, but are only just on the point of having enough of a crop to undertake that development.


***Figure 6***

**Animals** are being integrated, and we see this as a viable direction. We utilize horses, sheep, and poultry between the aisles of the crop plants, to “mow grass”, translate legumes to crop available nitrogen, and help in crop plant management. We are attempting to calculate animal inputs and costs, for direct comparison with machine alternatives, e.g. the use of diesel powered mowers to keep grass short enough to allow harvest and discourage rodents. This is very much a work in progress, but initial results are quite promising. Even large commercial vineyards/orchards may now hire sheep and goats to do careful work, replacing fossil fuel inputs with animals.

**Periodic coppice**, the practice of cutting the trees or bushes to the ground on a rotating basis, is the method used to manage the removal of old wood, or wood getting too tall for best management. Hazel rotations are approximately 8-12 years; chestnut coppice can be managed on a 20-30 rotation, depending on the wood products desired. On the longer rotation, harvest may yield poles for utilities or log cabin construction, both high value products, or small dimension lumber; the shorter rotation will yield fence post, vine props, charcoal and biochar. Rotations for hickory-pecan are not established, but first experiments show very strong coppice response.

**PROGRESS**

The neohybrid hazels are by far the most widely planted and tested of our crops; chestnuts next, and the hickory-pecans are only now being released to growers.

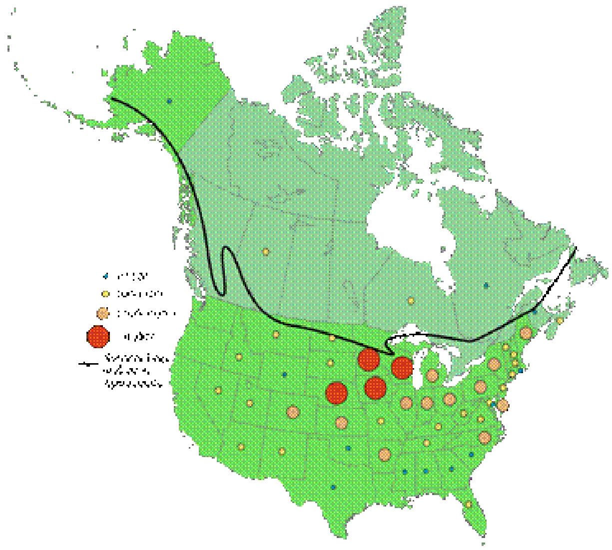

***Figure 7***

The map indicates numbers of our neohybrid hazels planted to date. Survival- and production; are of course different matters. As with all new crops, a number of catastrophic plantings have been made. Success, however, is also demonstrated.

In addition to the 5 universities previously mentioned, Badgersett Research has ongoing projects in cooperation with the U of Illinois St. Charles Horticultural station, Oberlin College, and our stockholders.

The original farm, outside Canton, Minnesota, is now in the process of converting from being primarily a research establishment to being the first full scale demonstration of actual integrated woody agriculture crop production.

At this point, BRC is prepared to proceed with commercialization.

Multiple scenarios for “bootstrapping” the crops to larger scale exist; one that frequently intrigues listeners is the concept of growing the hazels, entirely as an energy crop, beneath electric power transmission lines. At the moment, the cost of maintaining powerline right-of-ways is essentially a dead loss; invading trees are killed, grass is mowed; nothing is harvested- except the neighbors’ resentment. BRC is ready to spin off a subsidiary corporation, dedicated to powerline maintenance, and growing hazels beneath the lines for biodiesel and biomass fuel. The “green” publicity for the power company would be huge; the neighbors would be happier to have wildlife habitat and a wildlife corridor, with no pesticides used, actual cost to the electric company (and consumer) would be lower. When access to towers is needed for maintenance- there will be roads used for harvest, or the engineers are welcome to just drive over the bushes; they’ll recover next year. It’s just part of the cost of doing business.

The success of such a project depends on finding the right power company, with the will to experiment. We’d be glad to hear from any candidates.

Yes; Badgersett is seeking partners, and capital. And yes, you can come and see for yourself; please do.

Our Annual Field Day is just around the corner; Saturday, Aug. 18. Harvest is already underway; weeks ahead of schedule because of the heat. Please come.

We will have a crop; rain or no rain.

***Figure 8***