Sunspots : Is the Sun's Clock a Pendulum?

by Dr Philip R Goode

The curious dark spots which appear with clock-like regularity on the surface of the Sun have fascinated astronomers for centuries. The results of research, including studies of the current sunspot cycle, which is at or near its peak, challenges accepted ideas about them.

SUNSPOTS have intrigued astronomers since Galileo first used a telescope to watch the motion of these curious blobs. He noticed that the sunspots were concentrated in belts lying at latitudes near the equator; and his observations helped him deduce that the Sun had an axis of rotation, on which it turned about once a lunar month.

In the middle of the last century, after 40 years of observing the Sun, the German astronomer Heinrich Schwabe showed the sunspot numbers reached a maximum about every ten years, and then declined.

At the same time, the English astronomer Richard Carrington observed that the sunspots worked 0their0way from latitudes 20 - 30 N. and S. to 5 -10 N. and S. where they disappeared, over the 10 years from the start of a new cycle. Further, Carrington tracked the spots as they rotated around the Sun, showing that they did not all have the same period of revolution.

In particular, he saw that the closer the spots came to the equator the quicker they went around the Sun. That finding showed the Sun did not behave like a solid-body, but had a rotation of less than 27 days near the equator and as much as 40 days at the poles.

Classic Contribution

Carrington's discovery of differential rotation was on of the classic contributions of an amateur astronomer to the advancement of science. In a more detailed analysis of the sunspot records later in the 19th century, Rudolf Wolf, of Switzerland, concluded the time from the start to maximum sunspot activity was, on average, closer to 11 years.

Then early in this century, the American astronomer George Ellery Hale showed that the sunspots were associated with strong magnetic fields. In his investigations, he developed an astronomical instrument that exploited a laboratory discovery made a few years before by Pieter Zeeman, the Dutch physicist. Zeeman found that when an intense magnetic field surrounds a source of light, it splits the light beam into an atomic spectra of elements of characteristic patters.

In the first astronomical application of the Zeeman effect, Hale observed that light from sunspots, unlike other regions of the Sun's surface, showed the spectral pattern of Zeeman splitting. He also found that the sunspots tended to appear in pairs with opposite polarity, like the opposite ends of a bar magnet.

Further, in the first 11 years, spots of one polarity lead in the direction of rotation in the northern hemisphere, and those of the opposite polarity lead in the southern hemisphere. Then, for the next eleven years, the polarity of the leading spots is reversed; thus, a complete sunspot cycle lasts about 22 years.

It is commonly believed, with good reason, that a dynamo-type mechanism, shown in the illustration, provides an internal solar clock driving the activity seen on the surface.

Buoyant Magnetic Tubes

In this explanation of solar activity, there is a weak dipole magnetic field inside the Sun; as though there is a bar magnet inside the Sun. While, of course, there is no bar magnet, the sun's internal differential rotation shears this magnetic field, wrapping it tightly several times around the Sun. The wrapped field is usually called a toroidal magnetic field. The stretching and overlaying of the field lines intensifies the field and it becomes buoyant in this process; floating to the surface in toroidal tubes shaped like donuts.

Where the tubes erupt through the solar surface, sunspot pairs are formed. Toward the end of the first 11 years of the cycle the lagging polarities drift toward the poles and the Sun's magnetic field is reversed.

The shear of differential rotation comes into play again and tubes of magnetism of the opposite polarity are formed. So when these tubes erupt through the solar surface, the sunspot pairs are formed with the opposite polarity of those of the first half of the cycle now leading in the direction of rotation. This simplified picture of the dynamo reflects the deductions about the internal origin of activity based on nearly four centuries of observations of the solar surface. In the past few years, seismic analyses of the Sun's interior have shed new light on the activity clock. As in terrestrial seismology, soundwaves are generated by starquakes and the characteristics of the soundwaves are influenced as they pass through the interior of the star.

So each soundwave samples the interior in its characteristic way. And with a sufficient variety of soundwave data, the temperature or rotation rate, in particular, may be inferred as a function of radius.

Listening for Sunquakes

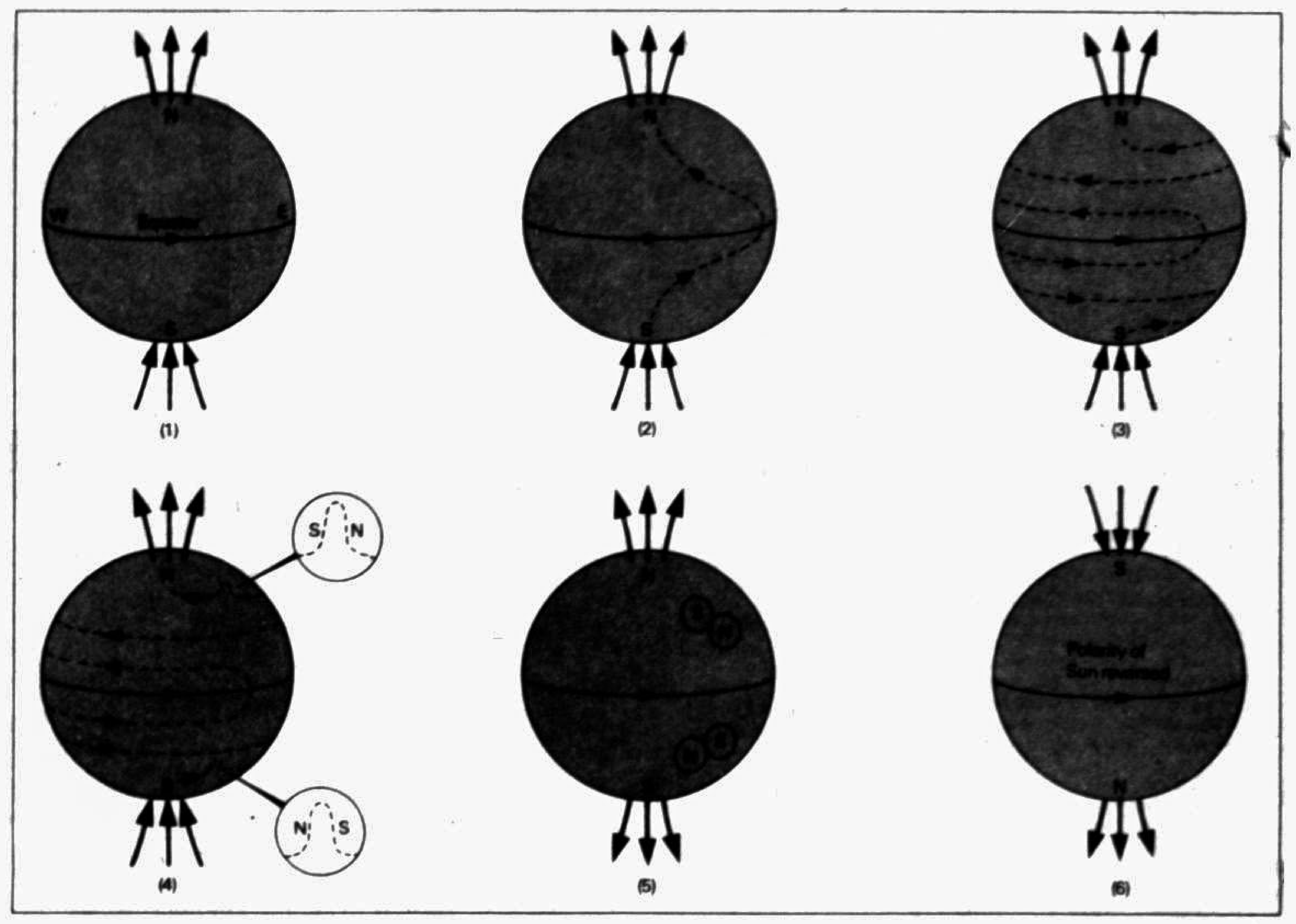
Of course, there are differences between terrestrial and solar seismologies. On one hand, sunquakes are continuously generated in the outermost turbulent regions of the solar interior. On the other hand, they cannot be "heard" by seismic listening devices but are seen by the blinking of the Sun.

The recent knowledge about the Sun's internal rotation from the study of solar quakes shows that surface-like differential rotation occurs throughout the outer 30 percent of the Sun by radius. In this outer 30 percent of the Sun the energy transport mechanism is turbulent convection, much like the turbulent convection that occurs in a coffee percolator. Near the bottom of the convective region in the Sun, there is a sharp transition to that of a body rotating with the characteristics of a solid with a period of about 27 days.

Thus, it seems fair to regard the volume just beneath the convection zone as a rotating solid shell.

Many researchers suspect that the entire volume beneath the convection zone rotates like a solid ball. Until recently, this seemed to be consistent with the seismic data. The region beneath the convection zone is the radiative interior; which earns its name because the energy transport mechanism is radiative transport. When a metal pipe is heated at one end it becomes warm at the other end via radiative transport.

The helioseismic rotation law is simple but it inconsistent with that predicted by the dynamo picture as it stands today. The dynamo predicts a rotation law which is constant through the convection zone, along any imaginary line which is parallel to the rotation axis.



The elementary dynamo picture of the solar activity cycle is illustrated in six steps leading through eleven years of the twenty-two year cycle. The Sun is rotating from west to east. At stage (1) the dipole field is illustrated with its north and south poles. The rotation rate decreases with increasing latitude and is most rapid at the equator. Inside the Sun the dipole field is "fixed" to the solar material and the differential rotation causes the field lines shown by dotted lines to be stretched gradually, into a toroidal geometry, or tubes, as indicated in time steps (2) and (3). The toroidal fields have opposite senses in the northern and southern hemispheres. Stage (4) shows two toroidal loops erupting, becoming pairs of spots with opposite polarities leading in the two hemispheres. Stage (5) shows the two spot pairs of which the polarity of the lagging spots drifts toward the poles, causing a reversal of the polarity at the end of the first half of the cycle as illustrated stage (6).

During the 1960's when the dynamo theory was under development, it was generally thought that the dynamo was distributed throughout the convection zone. However, such a dynamo would produce magnetic tubes that would be too buoyant to be held down as long as the activity cycle would require. The tubes would float to the surface in weeks rather than years.

In the last few years, the dynamo theorists used this to argue that the seat of this dynamo is near the base of the convection region (at about 0.7 of the radius). The seat of the dynamo should be in a region where the rotation rate is changing rapidly as a function of both radius and latitude. According to data from helioseismology, that describes the base of the convection zone and is consistent with dynamo theory.

Two Piece Clock

But the problem of describing the solar activity clock has now separated into two pieces.

First, what is the nature of the clock in the radiative interior that creates the magnetism that subsequently becomes the surface activity?

Second, how does that magnetism work its way from the radiative region to the surface?

In the idea of a pendulum-type clock, the revised view of the process controlling the sunspot cycle focuses on the nature of the clock in the radiative region and what is revealed about it from helioseismology.

While it is generally accepted that the solar clock depends on the nature of rotation and magnetism in the interior, there is no precise evidence from helioseismology to show the exact internal magnetism of the Sun. So there is still no direct measurement of the Sun's internal magnetism.

Yet a clear picture of the Sun's internal rotation is disclosed by helioseismology. Indeed, there is sufficient seismic information to ask whether or not the rate of rotation has changed through the current sunspot cycle.

In the current cycle of activity Dr Wojeciech Dziembowski and I determined the Sun's internal rotation rate from the seismic data of many observers. We concentrated on the equatorial plane because that is the region in which the rate can be most accurately determined.

Unexpected Result

After all, for any rotating sphere the rotation gets easier to observe the further the area of study is from the line of sight of the axis of rotation. We found a quite unexpected result; namely, that the most significant correlation between rotation rate and sunspot cycle occurred in the deep radiative interior.

— Spectrum.

OPTICAL COMPUTERS : A NEW ERA IN COMPUTER TECHNOLOGY

by Hasan Mahmood

COMPUTER has become an integr al part of the modern life in all the developed countries, where they are using computers almost in every walks of life, starting from simple computations and household applications to the high-tech war fare and space technology.

Though the developing countries are just getting acquainted with this widely used and highly capable device, it is not very far when we will also start using this device to meet all our requirements.

The most enchanting feature of a computer is that one need not know anything about its hardware details to operate and work with it. Just a little knowledge of software and operational characteristics can enable anyone to work with a computer. Hence, it is impractical to expect someone to know about the internal working of a computer unless he or she is a technical hand in this area. But almost everyone must be knowing atleast this much that computers till today make use of electrical signals to process data. All internal operations in a computer are performed with the help of Binary Number system where we make use of only two numbers, i.e. 1 and 0. Every computer is mainly a collection of switches, each of which is either 'ON' or 'OFF' at a particular time. These two states are termed as "logic levels" in computer technology and represented by the two numbers 1 and 0 respectively which are called 'Logic 1s' and 'Logic Os'. The machine is able to manipulate information that is encoded into a series of Is and Os, which correspond to the ON and OFF positions of the switches. All these are done electrically as already mentioned.

But have you ever thought whether all these could be done optically too, giving rise to an optical computer? Here the term optical computer necessarily means a general purpose computer that could use pulses of light rather than electrical signals to process data. From the theoretical considerations, it could be possible to device an optical switch to produce 'Logic Is' and 'Logic Os'. An optical switch is essentially a tiny mirror. When it is on, an incoming light beam is reflected out again representing 'Logic I' state. A second light beam, called the control beam, can signal the mirror to become opaque. The switch is then off and no light is reflected representing 'logic O' state.

The basic unit of light beam is known as photons. Theoretically, these photons can be much better than electrons for moving signals through a computer. It is obvious that there are specific reasons for this. First of all, photons can travel about ten times as fast as electrons. Secondly, electrons, being charged particles, react with one another whereas beams of photons, which have no mass or charge, can cross through one another without interference. Thus while electrons must be confined to guied wires, photons can move in free space. This could open the door to radically new and different computer designs, including so-called parallel — processors that could work on more than one problem at a time instead of one after another, as today's serial computers do.

But harnessing the computing power of light has proved to be a daunting challenge. The earliest attempts to build an optical computer date back to the late 1950s, when researchers experimented with mercury-arc lamps and even sunlight. Not much happened until the early 1960s brought the invention of lasers, devices that could concentrate light into powerful, high-precision beams. IBM spent four years and $100 million trying to develop a machine that uses laser beams to operate the multiple "ON-OFF" switches that are the heart of all computers. Unfortunately, the switching operations required too much energy, and the devices often overheated. Eventually the company virtually abandoned the project as unfeasible.

The field of optical computing faded into relative obscurity, but it was revived in 1986 by a break through at AT &T Bell Laboratories in New Jersey. Research Scientist David Miller developed the world's tiniest optical switch, a thin chip that in its latest version measures no more than 10 micro meters (0.00004 in.) on a side. Made of advanced synthetic materials, the device can turn on and off a billion times a second without overheating. These switches became the building blocks for an optical processor recently invented by Alan Huang, a 41 year old engineer at AT&T Bell Labs.

But even a few years back, when Alan Huang first revealed his plans to build an optical computer, most of his fellow US scientists dismissed his idea as hopelessly quixotic and impractical. Huang was laughed at and called a quack and dreamer by some scientists while delivering a lecture on this subject. Even once a part of the audience walked out too. Huang recalls, "I began to have computer nightmares, but I never doubted that it could be done. I wanted the last laugh".

At last though not entirely, at least partially, Huang's dreams came true as in February, 1990, Huang and AT & T unveiled an experimental computing machine based on optics rather than electrons, the first of its kind that took five years to develop. The device is a crudely configured collection of lasers, lenses and prisms-far cruder than even the most basic computers: it has no permanent memory and the only function it can perform is counting simple numbers. Just a small fraction of thousands of switches are connected. But this would serve as the basis for future optical computers 100 to 1000 times as powerful as todays most potent super computers.

The potential applications are stunning: robots that can see; computers that can design aircraft from scratch; processors that swiftly convert spoken words into written text and vice versa. Such optical computers may be still years away, but Huang feels complacent as his machine proves that his principle works and he thinks computer makers will soon replace wiring inside their machines with optical circuits. He is also sanguine that some 30% of super computers will use optical inter connections by 1995.

Not only Huang, many other scientists too are already predicting that the device will have an impact similar to that of the integrated circuit (IC), which made small personal computers possible. David Casasent, director of Carnegie Mellon University's centre for optical computing, calls Huang's work "an important first step" that has "advanced the clock" of the new technology.

Though many scientists are still skeptical about the possibility of real optical computers, there is no ambiguity about at least one thing that Alan Huang's invention will help exploring a new era in the field of computer technology.

Automatic Research Station In the Eternal Ice

FOR climate and environment researchers, measurement data from the Antarctic is of great importance, but investigations are particularly tedious because the transport of supplies for the manned research stations in rough terrain is expensive and very arduous. In the near future, however, an automatic measurement station, developed by scientists at the Alfred-Wegener Institute for Polar and Marine Research in Bremerhaven, will offer assistance. It is currently being tested in North Sweden and is to be employed without personnel in the Filchner Ice Shelf in the Antarctic at the end of 1991.

As a precaution, the most important instruments are present in duplicate so that this fully-automatic station which is to provide continuous information regarding the behaviour of the ice as well as of the ocean currents underneath, can operate trouble-free and maintenance-free for a whole year. The energy supply, which also encompasses an emergency power unit, is provided by two diesel generators, for which a total of 18 tonnes of fuel are available. The probes, sensors and data gathering systems necessary for the measurement processes are housed in a central measurement container and the temperature of each can be regulated separately by means of an air conditioning system.

A small-scale satellite for the direct and constant transmission of the measurement data was developed by students of the Technical University of Berlin and provides the opportunity for the scientists in Bremerhaven to monitor and control the instruments in the Antarctic from a distance. This will greatly surpass all battery-operated measurement systems employed thus far, which require maintenance on the spot at regular intervals. A further advantage of this automatic measurement station, which is also more environmentally-friendly, will be that its equipment corresponds to just one percent of the supplies required for the manned AWI research station Georg von Neumayer with a total weight of approximately 2,000 tons.

— GRS.

"ECOLOGICAL DATA BANK" FROM OUTER SPACE

SINCE 1972, an increasing number of satellites has observed the earth and supplied scientists with vast quantities of data concerning the earth's atmosphere and surface. The Remote Sensing Centre of the Deutsche Forschungsanstalt fur Luft — und Raumfahrt, DLR (German Aerospace Research Centre) in Oberpfaffenhofen has participated in this development from the start and made successful efforts to come up with efficient methods of evaluation.

So far, three satellites have been particularly helpful in supplying ecologically useful data: the weather satellite NOAA, as well as the remote sensing satellites LANDSAT and SPOT. Now a new satellite is to be launched, one which will send such a tremendous flood of raw data back to earth that it will not be possible to utilize it unless major efforts are made and new systems are developed for this purpose. It is the European Remote-Sensing Satellite, termed ERS-1 in short. Its payload consists of six instruments capable of recording a wide range of characteristic quantities. For example, by scanning the surface of the oceans, they can measure not only the length and height of waves but also the direction and speed of the wind. In addition to this, ERS-1 will be able to determine the surface temperature of water and the degree of humidity in the air. One hopes that this data will help to explain more accurately the influences which oceans have on the earth's climate.

The most important instrument on board is a radar scanner which can take pictures of the earth's surface even through a cloud cover or at night. These pictures show up objects as small as 30 metres in size, whereas the resolution provided by the NOAA satellites was only about 1000 metres.

Moreover, the new satellite will follow a polar orbit at an altitude of about 800 kilometres, thus being able to scan virtually all of central Europe in just three days, covering a strip of land 100 kilometres wide on each pass.

However, this data will be gathered in such large quantities that is will not be possible to store it temporarily on board and wait until the satellite flies over a suitable ground station before the data is transmitted; instead, it will have to be beamed down to earth immediately after it has been recorded. For this reason, the European Space Agency ESA, in co-operation with several non-European countries, arranged for a network consisting of 24 ground stations to be set up.

Elephant Grass as an Energy Plant

ELEPHANT grass has caused a sensation as a "magic plant" recently, and not only in the German media, because it can allegedly solve all energy and agricultural problems not just ecologically, but also economically, both as a supplier of building material and also as source of heat and fuel. This species of reed has attracted the attention of researchers because it produces significantly more biomass than other cultigens.

The reason for this high productivity of elephant grass (Miscanthus sinensis giganteus) is that is belongs to those specialized plants which have developed an efficient variation of photosynthesis, which generally involves the conversion of carbon dioxide and water into sugar, cellulose and starch by means of light energy. In "normal" plants, one precursor of these carbohydrates consists of a molecule which contains three atoms of carbon (C). Hence their name, C_3 plants, In the case of elephant grass, however — just like corn, sugar-cane and millet, for example — the corresponding molecule consists of four carbon atoms, which is why they are termed C_4 plants.

C_4 plants, which are indigenous to hot, dry regions, possess some remarkable properties. If a C_4 plant and a C_4 plant are placed together under a sealed bell-jar exposed to abundant light, the C_4 plant withdraws so much carbon dioxide from the that a kind of reverse photosynthesis occurs and C_3 plant dies. One advantage of C_4 plants if their low water requirement : They normally require less than half of the approximately 800 grams of water metabolized by C_3 plants in order to form one gram of dry mass.

This becomes clear in the case of elephant grass, which yields twice the amount of biomass, i.e. approximately 25 tons per hectare, than wheat, when grain and straw are taken together. When burned, this biomass corresponds to the energy of 10,000 liters of heating oil.

This sounds impressive, but is by no means sufficient to make its cultivation economical at today's oil prices. Experts reckon that production would require a subsidy of approximately 800 DM per hectare. Even at that, elephant grass would clearly be cheaper than all other energy plants. If wheat were to be combusted, the subsidy requirements would be more than twice as high, the production of vegetable oil from rapeseed would require 1,900 DM per hectare, 2,500 DM per hectare would have to be subsidized for the alcohol production from wheat and as much as 4,500 DM from sugar beet. However, one had to rely on rough estimations for elephant grass, as thus far this kind of reed has only been cultivated on an area of slightly more than one hectare. Nonetheless, in Bavaria, an increase in the cultivated area 20 to 25 hectares is imminent.

Elephant grass is regarded as being undemanding, at least as far as fertilizing is concerned. However, it has yet to be revealed exactly what this means in terms of its long-term cultivation in Central Europe. Even the planting is expensive. Partial yields can only be expected after the third year of vegetation, and in the fourth year the reeds are fully grown. As regards the plant's life-span, estimates vary between ten and 15 years; a lot will depend on the cultivation of the cultures, which has still to be investigated more closely.

It is totally unclear how laborious it will be to recultivate the areas afterwards because the roots, which reach down as far as three or four meters, from massive clumps. Possibly, special machines will have to be built. The harvesting machines, finally, will require huge investments as the cultivation of elephant grass as a source of energy will only make sense if the reeds are compressed into a combustible form immediately upon reaping.

Elephant grass undoubtedly offers an interesting alternative to energy plants studied thus far. Industry has also be come aware of this. The chemical concern BASF Aktiengesellschaft in Ludwigshafen has recently cultivated elephant grass on an area of 1,000 square meters in its agricultural test center Limburgerhof in order to methodically examine the culture condition sand yields.

— Peter Bensberg